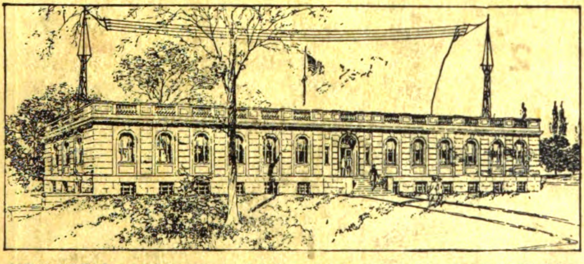
LEFAX
RADIO HANDBOOK

THE REAL AUTHORITY ON ALL RADIO SUBJECTS—IN EVERYDAY LANGUAGE—BY THE HIGHEST GOVERNMENT EXPERTS—NOT OPINIONS—NOT HEARSAY—BUT TRIED AND TESTED FACTS



NEW RADIO LABORATORY OF THE U. S. BUREAU OF STANDARDS

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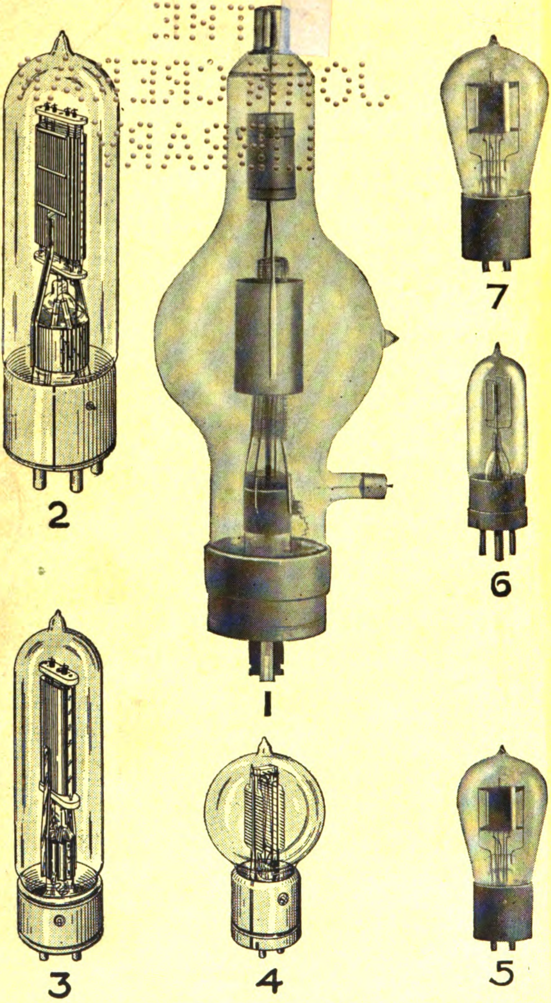

Electron Tubes
The Heart of the Modern Radio Phone

No. 1—1000-Watt Transmitting Tube.
No. 2—250-Watt Transmitting Tube.
No. 3—50-Watt Transmitting Tube.
Nos. 4 and 7—5-Watt Transmitting Tubes,
(also used as power amplifiers)
No. 5—Detector and Amplifier (storage battery).
No. 6—Detector and Amplifier (dry battery).

Preface

Radio is taking its place in modern life alongside the telephone, the phonograph, and the automobile. Civilization is communication, and radio is the unique supplement of all other means of communication. With its novelty and mystery, radio has an appeal to everyone, but it has also rapidly increasing real utility.

The life of the sailor in mid-ocean depends upon it. It is of routine commercial value to the business man and it is a great force for the education and entertainment of the whole population. One who is new to the subject wants to know what radio really does and can do; what is needed to receive or use radio; and how it works. This handbook aims to give just that information without too much technical explanation. Practical information on the use of receiving apparatus is given in Chapter 2, explanations of how it all works being left to later chapters.

In the apparatus section the reader will find illustrations and detailed description of the various pieces of equipment that enter into a modern radio phone receiving set. An effort has been made to make this section as complete as the limited space assigned it will allow. It will often facilitate understanding of the text matter to turn to this section and see an illustration of the apparatus discussed. The reader is urged to use the apparatus section for this purpose.

Radio is bound to seem mysterious at first. It is invisible; it can not be sensed directly, like sound or light. It does not stay on a track or wire but penetrates everywhere. It is a most willing servant of mankind, carrying all manner of signals, sounds, electric currents, and messages.

The authors and publishers will be glad to hear from holders of the book telling of any errors or of important points not fully covered.

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Free Service

New developments in radio including new apparatus and hook-ups will be described in *Radiofax*. This publication will be mailed to all holders of the handbook for one year without charge. *Radiofax* pages are the same size as the handbook and thus can be easily transferred.

Fill out and mail the postal card immediately.

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CHAPTER ONE

WHAT RADIO DOES

The word radio comes from "radiate." Radio is an electrical action which is radiated out in all directions through the air. Just as there is one kind of electrical action known as the electric current which goes along wires and turns machinery and lights our homes, so radio is another form of electricity. Instead of going along wires it radiates out in all directions from the place where it is started. Because radio thus produces an electrical effect at a distance without connecting wires, it was formerly called wireless. Radio has possibilities that are not found in the ordinary electric current, just as an automobile is free from some limitations of a trolley car confined to tracks.

Since radio spreads out in all directions from the place where it is started, its effect can be picked up at an unlimited number of places simultaneously. It may thus be spoken of as a highly democratic, even communistic, kind of communication, being available to everyone. It is very similar to sound waves. Sound similarly spreads out in all directions through the air and can be heard by many people simultaneously. Radio is not sound, however, because it is electrical in its nature. Radio is in fact very much like light—except that instead of using our eyes to detect it, we use special receiving instruments. Radio is practically instantaneous. It spreads out with the same speed as light, 186,000 miles per second.

As will be explained in chapter 4, radio consists of electric waves radiated out from a special kind of outfit called a radio transmitting station. It will also be shown how these electric waves are produced by the action of electric current in the transmitting station. As soon as the reader realizes, however vaguely, this fundamental fact that radio consists of electric waves proceeding out from the transmitting station, he is well started on the road toward understanding what radio can and can not do. The form of the waves is determined by the nature and variations of the electric current at the transmitting station. This current can be varied in accordance with the dots and dashes of ordinary telegraphic signalling or can be the kind of current flowing in an ordinary telephone line. Further consideration of how the radio wave

can thus carry any form of signal or even speech or music may very well be deferred until chapter 4.

In the use of the ordinary wire telephone the sound produced at the transmitting end is converted into a varying electric current which flows along the wires, this current being changed back again into sound in the telephone receiver at the other end. Radio telephony is similar except that there are no connecting wires. There must be arrangements at the transmitting end for converting the speech into an electric wave and at the receiving end arrangements for converting the received electric wave into sound. The great difference between the two is that the electric action has been carried by means of electric waves passing through the air instead of by means of electric current passing along a wire. Consequently it is possible to transmit and receive by radio anything that could be transmitted and received by the wire telephone, radio having the great additional feature (advantage in many respects and disadvantage in some) that it can be received by anyone in any direction from the transmitting station. This book will deal primarily with radio telephony, as this is of most interest. There is little difference in the receiving of telephonic or telegraphic signals.

Uses of Radio.—Radio has taken its place as one of the great means of communication comparable with the ordinary telephone and the newspaper. In the communication business proper it is recognized as an additional agency of communication comparable with the wire lines and the cables. It is particularly useful in marine and aerial transportation both in furnishing special aids to navigation and in carrying on of communication, especially distress signals. It is perhaps most similar and supplementary to the newspaper in the work of broadcasting news, entertainment, etc. It is worth while to consider the following list of the principal uses of radio:

1. Broadcasting.
2. Communication with moving ships, aircraft, etc.
3. Transoceanic communication.
4. Communication between two points on land.
5. Non-communication uses.

Radio broadcasting is the most recent but the most important use of radio. It is now possible in most sections of the United States, by means of suitable receiving apparatus which the layman can learn to operate, and which may be easily installed in any private home or office, to pick up valuable and interesting news, information, and music, broadcasted on regular schedules by various radio telephone transmitting stations. By the addition of amplifiers and loud speaking horns, now on the market, the speech or music received may be reproduced as loud as desired,

and thus be made available to large gatherings of people without the necessity of separate head receivers for each listener. The value of the radiophone broadcasting service is rapidly being increased by the construction of additional transmitting stations in various sections not now reached with regularity. The services of existing stations are being extended; many stations are sending out regularly such items as weather forecasts, market prices and data, stock market reports, the latest news, standard time signals, church services, theatrical entertainments, speeches, lectures, and music of all kinds. Broadcasting is discussed in later sections of this chapter.

The use of radio at sea was the first important application of radio and still continues one of its most important services. Besides regular messages between ships and land, reports of ships' positions are made by radio and ships receive from shore stations weather warnings and general and hydrographic news. So important is the use of radio on ships that the use of radio on shipboard is compulsory and no vessel can leave a United States port without a certificate from a U. S. radio inspector that its radio equipment is in working condition. Coast radio transmitting stations are required to cease operating for a period of 2 minutes every 15 minutes, to listen for possible distress signals from ships. This is the reason that broadcasting stations near the seacoast interrupt the broadcasting once every 15 minutes.

The use of radio on commercial aircraft is practically universal. In foggy weather the use of radio on an airplane is as necessary as on a ship at sea. It is now technically possible to connect the ordinary wire telephone lines to the radio apparatus so that conversation can be carried on from the ordinary house telephone with a distant ship or airplane which is equipped with radio apparatus. It is only a question of time till the telephone companies furnish such service regularly.

Radio is an alternative to the submarine cable for transoceanic communication. Commercial radio service across several oceans has been maintained for several years in competition with the cables. It has the great additional advantage that persons on two different continents can speak to one another directly instead of through code telegraphy, an advantage not possible with the cable. Such radio telephony however is not yet a regular service. To cover these great distances very high power radio stations are used. All of the great nations are now extending their high power radio systems, their great usefulness to business being evident. For this kind of service the fact that radio can be picked up in many places in all directions from the transmitting station is a disadvantage and indicates

that for transoceanic communication radio can never entirely replace the cable.

For reasons which will be explained later, radio messages more or less interfere with one another. Consequently it is necessary that communication which can quite readily be carried on by other means than radio should utilize such other means. Radio is, therefore, not used much for communication between two points on land inasmuch as wire telephony or other means of communication could be used. There are, of course, exceptions in the case of deserts, mountain regions, remote forest regions, etc. One kind of communication between two points on land where radio may be suitable is communication with moving trains and other vehicles. This has been done but not actually developed to any considerable extent. It is in fact likely that means will be found to utilize electric currents guided along the rails or nearby wires for railway communication so that radio will not be needed for this purpose. The only extensive use of point-to-point radio communication on land is the radio work of amateurs. In the relaying of messages across the country an extensive communication system has been built up by the United States amateurs.

A large number of uses of radio which are not communication have already been developed. Among these are various aids to navigation. A radio station automatically sending out signals acts as a radio beacon. These signals can be received by ships or aircraft and by means of them the vessel can navigate just as by the aid of beams from a lighthouse. The United States Bureau of Lighthouses is installing a number of such radio beacons. Various radio navigational aids for aviation are being worked out. One that has been developed is the use of radio signals at a landing field to facilitate airplane landing. Another non-communication use of radio is the transmission of time signals giving standard time twice daily in the United States. By means of radio, distant control of any desired machinery or motion is possible. The radio signals can operate a relay which will throw into or out of service any desired machinery. In this way aircraft and ships are started and operated without any persons on board. Methods have been worked out for transmission of photographs, thumbprints, and writing by radio. This is still in the experimental stage, but handwriting has been reproduced across the Atlantic by radio.

Importance of Broadcasting.—It was only when radio began to be used for broadcasting that it attracted the widespread interest of the general public. Broadcasting is transmission to an unlimited number of receiving stations without charge at the receiving end. So long as radio was used with only one particular

receiving station in view to receive the message, its greatest possibilities were untouched. Since it spreads out in all directions and can be received by an unlimited number of persons, it is obviously of most use when the material transmitted is of interest to a large number of people. Weather and other news of interest to ships has been broadcast by radio telegraphy (code) for many years. The year 1921, however, saw the real beginning of broadcast radio service. Government news of market conditions of interest to farmers was transmitted from six Government stations. This information was transmitted in telegraphic code. It was picked up by amateurs and distributed to the newspapers and to farmers in various ways. It was not long until universities, electric manufacturing companies and others secured permission from the Government to broadcast this information by radio telephone. At the same time a number of electric companies, newspapers, etc., began sending out music and lectures by radiotelephone. When people learned that actual words and music could be heard, radio bounded into popularity. Since, moreover, only relatively simple and cheap receiving apparatus was required to hear all of this material, the popular interest in radio grew rapidly. In 1921 also the broadcasting of important financial and political news by radiotelephone was begun in Germany and Holland.

The importance of radio broadcasting as a means of disseminating news, instruction, and entertainment is generally recognized. It is an established and valued supplement to the newspaper, the theater, and the phonograph, and excels each of these in some respects. The proper development of such service has received the attention and guidance of the Government, and all sorts of organizations, newspapers, communication companies, schools, churches, and other Government and commercial concerns have provided radio broadcasting service. It is not possible for all the broadcasting to be done that all interested would desire, because of the interference of one radio transmission with another. This matter is regulated by the U. S. Department of Commerce.

An interesting illustration of the value of broadcast news is the utilization of such service by exploring expeditions. Arctic exploration parties carry radio transmitting and receiving apparatus, and both receive the daily news and entertainment from high power broadcasting stations and send out stories of their adventures.

Broadcasting Wave Lengths.—In the early development of radio broadcasting, all entertainment and general news was transmitted on the "wave

length" of 360 meters, and official Government news on the wave length of 485 meters. This matter of wave length is of the greatest importance. The waves which constitute radio are all in the same air and so are capable of interfering with each other. The thing that saves the situation and makes it possible to use radio at all is that it is possible to "tune" radio receiving apparatus so as to receive waves of a particular wave length (or wave frequency) and not receive those of other wave lengths. "Tuning" will be explained later. Practically its effect is that turning to different points on the dial on the receiving set makes the set pick up waves of different wave lengths.

The general idea of wave length is explained in chapter 4, page 13. It can be readily understood by comparison with sound waves. A sound wave of higher frequency has a shorter wave length than a sound wave of lower frequency. The same thing is true of radio waves. The wave length or frequency is determined by what takes place in the transmitting antenna. Any particular transmitting antenna sends out a radio wave of some particular wave length or frequency just as a piano string when sounded sends out a sound wave of some particular wave length or frequency. The wave length is the distance from one wave crest (or maximum) to the next. Radio wave lengths are anywhere from 100 to 25,000 meters. The meter is about 39⅜ inches, and is the unit of length used all over the world except in the United States and the British Empire. Wave length has nothing directly to do with the distance to which a radio wave spreads out. Similarly, a sound wave or a water wave may have a wave length of one foot but such a wave could travel a distance of very many feet.

All of the more popular broadcasting being done on the same length (360 meters), it was impossible to avoid some interference. The loudness of the received signals decreases with distance from the broadcasting station, so it is possible for that reason to hear a nearby station without being disturbed by a remote station. When the broadcasting stations were near together, however, it was necessary for them to broadcast at different times of day. When this was not done, it was still sometimes possible to "tune in" the station desired and "tune out" one not desired because the wave lengths were usually not adjusted accurately and one might be a little greater than 360 meters and one a little less.

The interference became so troublesome that it was necessary to make arrangements whereby broadcasting stations could have different wave lengths. Radio is regulated, and wave lengths are assigned, by the U. S. Department of Commerce. The Department called a conference in March, 1923, to draw up a plan which would give more wave lengths for broad-

casting and still leave enough for the various other uses of radio, such as ship and aircraft communication. This conference divided broadcasting stations into the following classes:

Class A stations—that is, stations equipped to use power not exceeding 500 watts. In this class the radio inspectors, in co-operation with the station owners, assign distinctive wave lengths to each station so far as is possible in the area from 222 to 300 meters.

Class B stations—that is, stations equipped to use from 500 to 1000 watts. These stations are licensed on special wave lengths from 300 to 345 and from 375 to 545 meters. There are forty distinct wave lengths available in this range, and each is assigned to a certain locality, there being no duplications except for a few cases of use of the same wave by two localities, one on the Atlantic and the other on the Pacific Coast. Where more than one Class B stations operate in the same locality, they must operate on the same wave length and avoid interference by operating at different hours.

Class C stations—comprising all stations originally licensed for 360 meters. In this class no new licenses will be issued for stations on 360 meters. Stations which do not wish to move under the general plan may remain at 360 meters, but they will necessarily be subject to some interference at best.

Broadcasting Development Class—To encourage scientific development of broadcasting and the apparatus used for this purpose, licenses of this class will be issued to owners of stations having transmitting and receiving equipment of their own design and manufacture. Such stations are to be used for the development and improvement of broadcasting and to have adequate laboratory and manufacturing facilities and personnel, with sufficient skill, training and experience to insure progress in development work and the best obtainable quality of broadcasting.

The recommendations of the conference were placed in effect on May 15, 1923, in the case of class B stations. The changes in other stations followed shortly thereafter. The complete schedule of wave lengths for all classes of radio communication is given below.

One of the best provisions of the new arrangement is that by which the higher power broadcasting stations are assigned individual waves in the range from 300 to 545 meters (1000 to 550 kilocycles). Only one broadcasting station on each of the wave frequencies within this range is in operation at any given time (except for some duplication of waves on the Atlantic and Pacific coasts which is being tentatively allowed by the Dept. of Commerce). That is, waves approximately forty in number are ten kilocycles apart. This means that

person having a receiving set so good that he can receive from all parts of the country is not in danger of hearing a beat note from two stations on nearly the same wave frequency, nor will two stations be heard working on the same wave frequency. This has resulted in the development of extraordinarily perfect broadcasting service and has greatly stimulated the development of high quality receiving apparatus.

The conference recommended that wave frequency expressed in kilocycles be used primarily, wave length in meters being given in parenthesis when desired. We urge our readers to familiarize themselves with and think in terms of kilocycles as soon as possible, inasmuch as waves are now assigned in even values in kilocycles, the wave length in meters being calculated therefrom. It is expected that the use of the term "wave length" in radio will gradually disappear.

Wave Length Regulation.—Not only in broadcasting but in all uses of radio, the whole success of the communication depends on proper use of the wave lengths. Certain specific wave lengths are assigned for certain purposes by international and national laws, and technical requirements determine the use of some others. The longer waves are more suitable for longer distances, because short waves are very much more absorbed or impeded by the surface of the earth over which they travel. Thus wave lengths from 8,000 to 24,000 meters are used in transoceanic communication. Very short waves carry specially well at night. Amateurs (who work mostly at night) use wave lengths less than 200 meters. The various other uses of radio are on wave lengths intermediate between these extremes.

Every transmitting station in operation makes it more difficult for receiving stations to hear other transmitting stations without interference. Therefore, no business which can be transacted by using other methods of communication should be conducted by radio. The number of wave lengths available for the use of radio stations is limited and in densely populated regions and in all important seaports the problem of radio interference is an extremely serious one.

Time Signals by Radio.—The system of transmission of time signals is as follows: Beginning 5 minutes before the hour on which the time signals close, the transmission of a series of dots is commenced. One dot is sent at the beginning of each second of time; the 29th second of each minute is omitted, and the last five seconds of each minute are omitted for the purpose of enabling the one who counts the signals to make preliminary observations before the closing signal. At the close of the final minute, the last 10 seconds are omitted. Then at the exact hour a long dash is transmitted, whose beginning marks the hour.

WAVE FREQUENCY ALLOCATIONS

Wave Frequency, Kilocycles, per Second	Wave Length, Meters	Class of Service
Above 2300	Below 130	Reserved. (See Note 1.)
2300	130	Government, CW, exclusive.
2300–2100	130–143	Reserved. (See Note 1.)
2100	143	Government, CW, exclusive.
2100–2000	143–150	Reserved. (See Note 1.)
2000–1700	150–176	Amateur, CW, ICW, Phone, exclusive.
1700–1500	176–200	Amateur, CW, ICW, Phone, Spk, exclusive.
1500–1350	200–222	Special amateur, and technical and training schools, CW, exclusive.
1350–1300	222–231	Aircraft, CW, ICW, Phone, non-exclusive.
1350–1000	222–300	Class A broadcasting, Phone, non-exclusive.
1000	300	Marine, CW, ICW, Spk, non-exclusive. (Note 2.)
1000–870	300–345	Class B broadcasting, Phone, exclusive.
835	360	Class C broadcasting, Phone, exclusive.
800–667	375–450	Class B broadcasting, Phone, exclusive.
667	450	Marine, CW, ICW, Spk, exclusive. (See Note 3.)
667–550	450–545	Class B broadcasting, Phone, exclusive.
550–500	545–600	Marine and aircraft, CW, ICW, Spk, exclusive.
500	600	Marine and aircraft, CW, ICW, excl. (Note 2.)
500–445	600–674	Marine and aircraft, CW, ICW, Spk, exclusive.
445	674	Government, CW, non-exclusive.
445–375	674–800	Marine and aircraft, CW, ICW, Spk, exclusive.
375	800	Radio compass, CW, ICW, Spk, exclusive.
375–315	800–952	Marine, Phone, exclusive.
315	952	Government, CW, ICW, Spk, exclusive.
315–300	952–1000	Reserved.
300	1000	Radio beacons, CW, ICW, Spk, exclusive.
300–285	1000–1053	Reserved.
285–275	1053–1091	Marine, Phone, exclusive.
275	1091	Government, CW, ICW, non-exclusive.
275–250	1091–1200	Marine, Phone, exclusive.
250	1200	Government, CW, ICW, non-exclusive.
250–235	1200–1277	Marine, Phone, exclusive.
235–230	1277–1304	University, college, and experimental, CW, ICW, exclusive.
230–190	1304–1579	Government, CW, ICW, Spk, exclusive.
190–120	1579–2500	Marine and point-to-point, non-government, CW, ICW, Spk, exclusive.
120–95	2500–3158	Government, CW, ICW, Spk, exclusive.

Note 1.—Available for special licensing by the Department of Commerce.

Note 2.—The 1000 and 500 kc/s (300 and 600 meter) waves are for calling and distress purposes, with a minimum of traffic.

Note 3.—Mobile service on the 667 kc/s (450 meter) wave is to be stopped between 7 and 11 p. m. local standard time, and to be transferred in so far and as soon as practicable, to wave frequencies below 500 kc/s (above 600 meters).

Factors Affecting Range of Receiving Sets.—The distance over which radio can be picked up varies with time of year, day and night, and other factors. It is sometimes possible to hear a station 1000 miles away at night while 200 miles would be the greatest distance covered in the day. An explanation of this, and of the fluctuations of signals that sometimes occur at night and other variations, has been published by the authors in "Radio Signal Fading Phenomena," in the Journal of the Washington Academy of Sciences, 11, p. 245, 1921. On account of disturbances of the electrical condition of the atmosphere, during midsummer, radio reception during daylight hours may be occasionally interrupted. At times, during the summer months, the strays may completely drown out the radio signals picked up by the receiving set. The idea that the addition of sensitive amplifiers to the receiving set will relieve the situation is erroneous. The amplifier amplifies the strays along with the incoming signal, so the amplified signal is often less intelligible than the signal received on a simple detector.

During severe electrical storms sometimes it is not only impossible to receive any messages, but it may be unwise, especially if the storm is accompanied by lightning discharges. At such times the antenna should be grounded to protect the apparatus and no attempt made to receive radio messages. Occasionally the transmitting range of a station will be limited in a certain direction owing to an intercepting dust storm. These atmospheric disturbances which give trouble in the use of receiving sets are discussed further, near the end of Chapter 2.

Present Status of Radio.—Radio is rapidly developing and popular appreciation of it is accelerating its expansion to fill the unique field of usefulness to which it is adapted. A word is desirable as to its shortcomings, so loudly are its advantages heralded. While the spreading out in all directions is an advantage for broadcasting and some other uses, it is a disadvantage in other ways. Radio lacks the secrecy or individual character of communication by wire, and cannot take its place. There is no calling up in radio with a call bell, as in wire telephony. That is a possibility, but it has not been developed; one way of doing it now is to use a powerful amplifier and loud-speaking telephone receiver.

RADIO

A Recent Lecture by L. E. Whittemore

U. S. Inter-Department Radio Advisory Committee

There was once a college teacher who advised a student not to go into the study of radio because he believed that there was no future to that subject. No one now denies that there is a future to radio, and it certainly has a present. All of my neighbors within a few blocks have antennas on their houses, and probably all of you have receiving sets in your own homes. I am the student who received that advice from his teacher, and it was given only about ten years ago; but I am glad to say that that teacher now realizes very strongly the importance of radio, and courses of study in radio are taught in his department.

Step by Step Development

Radio is an interesting mixture of theoretical and scientific research and of progress through brute experimentation or trial. Maxwell, in England, in 1867, predicted as a result of his mathematical studies that electrical waves might exist, and if they did exist would have certain properties and perform in certain ways. Later, electrical waves were produced experimentally by Hertz, who found that the mathematical predictions of Maxwell were true. These predictions describe quite fully the way in which waves leave a transmitting antenna and produce current in a receiving antenna. Theoretical and highly scientific studies of the emission of electrons from hot bodies and of the fundamental constitution of the molecules and atoms of matter have been made by many scientists. These are now applied very definitely in the construction and improvement of the vacuum tubes which we use in our radio receiving sets.

Among the experimental developments which have made the use of radio possible is the very fundamental one of Marconi, who about 1897 was the first to try the effect of a ground connection on his transmitting set. By using this connection he found, to his great pleasure, that the distance to which his station would communicate was enormously increased. During the war, the use of radio on aircraft was developed rapidly through the active experimentation of engineers, who tried this, that and the other form of antenna and apparatus arrangement for use where space is limited and a ground connection is not available. Two enthusiastic experimenters from the Bureau of Standards, also during the war, in spite of discouragement from their more scientific advisers, secured permission to conduct actual experiments with naval submarines, and succeeded in developing a method for radio communication between submarines even when the craft is submerged twenty feet

below the surface of the water. Many of our receiving circuits have been developed through patient experimenting, the result being of inestimable value, as we all know in the case of the Armstrong regenerative circuit.

Radio Law, Present and Future

Radio is a unique sort of public business. All messages use the same highway. When the owner of a transmitting station starts to transmit a message, he uses a part of this ether highway, employing a definite frequency or wave-length. This frequency must be chosen to avoid conflict with other messages. It is therefore essential that there be a central co-ordinating office or clearing house to make rules for the use of this ether highway and see to their enforcement. Such a duty is that of the radio inspection service of the United States Department of Commerce.

The regulation which the radio inspection service applies to radio communication is essentially directed to the technical features of the transmitting station and particularly to the external effect of the station; that is, it is important to consider the location, the power, the sharpness of the transmitted wave, and in some cases the direction in which these waves are transmitted, since all of these features have to do with the possible interference between this station and others which have an equal right to communication at the same time. The law under which this regulation is being done at present is an old, obsolete law passed in 1912. Our modern tube transmitting sets were not dreamed of at that time, and the restrictions written into that law are very meager, since practically the only kind of transmitting sets used were spark sets, which inherently caused much interference and could be used only for telegraphic purposes. Under this law, the Secretary of Commerce has no alternative but to grant a radio station license to an applicant. Up until recently, co-operation on the part of the users of radio has saved the day, but we cannot rely on this indefinitely. Shortly before broadcasting became so popular, a spark station in the center of New York persisted in operating to the great detriment of commercial and government stations in the vicinity. Nothing could be done under the law to require its discontinuance. If such a situation were to arise again, there would be hundreds of thousands of broadcast listeners suffering from the operation of this one transmitting station, and there would be no redress in the courts. The papers recently told us of an instance of radio heckling of political operators. A political address being broadcast by radio in Kansas City was spoiled for all of the listeners by the operation of an unfriendly radio station in the vicinity using the same frequency. There is now pending in Congress a new radio bill known as the White bill,

which, it is anticipated, will take care of these problems. The subject of radio is surely, as Secretary Hoover has said, the most technical subject on which Congress has been asked to legislate.

Features That Should Not Be Regulated By Law

There are two things which the present law does not cover and to which the pending legislation does not, and in my mind should not, attempt to apply. One of these is the censorship of the material which goes out from the broadcasting stations. The best means for determining what programs should be transmitted is a study of the letters which are received by the broadcasting stations from the listeners.

A broadcasting station manager knows well enough that if he does not please his listeners they will turn to other stations. The second of these is the control of receiving sets. Such control would be physically impossible. It would be like having to license or register the kitchen tables which people have purchased at stores or built for themselves of packing boxes and rough boards. Many complaints have come to the Department of Commerce, of interference from leaky insulators, sparking trolley wheels, elevator switches, X-ray machines and violet ray apparatus. These are real sources of noise for the broadcast listener, but their regulation by law would be practically an impossibility. We must look to education of the users of these electrical devices and to voluntary co-operation to minimize this source of trouble.

Radio broadcasting has grown up among us so suddenly and attracted so much attention that we sometimes forget the other services which radio renders. It is worth our while to run through the several other uses of radio and note the progress which they have made during the past year or so. High power radio stations for transoceanic service are now in operation in direct competition with the cables. Circuits have recently been opened from New York to Holland and Warsaw. The circuit to Rome has been made reliable and an experimental service has already been started between New York and the Argentine. Radio-telephony across the Atlantic from high power stations bids fair to become a commercial proposition. The high power radio station in Japan was of untold benefit to that country during the recent earthquake.

Navigation and Aviation

Radio is the only means of communication with ships, and its use in this field is increasing rapidly. In addition to the transmission of distress calls and messages, radio is commercially important for directing, rerouting or diverting ships which have already left their harbors. Ships have been using radio for many years, and on this account there is a great deal of old equipment still in

use. In order to keep down the interference, which is rapidly increasing, it will be necessary for ship stations to discard this obsolete apparatus and become equipped with modern sets. There have been readjustments in the frequencies assigned to ship services. The military departments have given up some of their frequencies for the use of commercial ships, in order that they in turn might give up some of their frequencies for the use of broadcasting.

Radio lighthouses or beacon stations are being installed along our coasts to enable ships equipped with radio direction finders to determine their position at sea in time of fog.

The use of radio on aircraft will undoubtedly be an essential factor in making commercial aviation possible. The dirigible Shenandoah was in communication with the Navy stations and with the broadcasting station at Newark, N. J., during her recent forced flight. In an experimental way, radio is being used for the control of airplanes in flight without the necessity for a pilot on board the plane.

Radio and Wire Telephony

Radio waves can be carried or guided along wires. The ordinary electric power lines on Staten Island have been used to furnish a broadcasting program to electric light users on the island who rented simple receiving sets from the power company. This method of guiding radio waves along the wires is used by electric power companies in mountainous regions where there is difficulty in maintaining telephone lines on poles. The radio waves often jump the gaps on the lines when they are broken down during storms. A pair of long-distance telephone lines can be used simultaneously for a large number of telephone conversations by putting on these lines appropriate radio currents of different frequencies, each frequency carrying a telephone conversation. If any of you have recently talked between Washington and Chicago by long-distance telephone, there is a fair chance that your voice was carried part of the distance by radio currents in such a way.

Radio Apparatus in Other Fields

Radio methods and radio apparatus are useful in many other ways. Recently the Navy Department exhibited an apparatus for determining the depth of the ocean. This apparatus employs some devices which are also used in radio receiving sets, and will doubtless make unnecessary the dropping of the lead and paying out long lengths of rope in order to determine the ocean's depth. Instead, an operator can sit at a desk and turn an adjusting knob, the dial indicating directly the distance in feet or fathoms. Radio is helpful in the determination of the difference in longitude between two points on the earth's surface and will enable surveyors to more accurately map the continents. The speed of

the radio waves is 186,000 miles per second, which makes the time of transmission almost negligible for distances on the surface of this earth. Apparatus quite similar to that which is used in radio transmitting sets is employed in electric furnaces which produce high temperatures and are useful in melting ores and metals. A certain automatic train control device uses tubes which are almost identical with the tubes which are employed in our radio receiving sets. One thing which radio will not do—at least in our lifetime, though it is dangerous nowadays to say that anything is impossible—is to transmit power over any appreciable distance for the operation of machinery. Radio, by its very nature, is a broadcasting proposition, and the power which is transmitted from a given station spreads out and is dissipated, by far the larger part of it being entirely lost. If one desired to use power for about ten minutes, costing one-tenth of a cent out in Kansas City, and were to attempt to transmit it from the radio station at Arlington, about one thousand miles away, it would be necessary to transmit during that ten-minute interval an amount of power which would cost one hundred billion dollars.

We have become so accustomed to turning the knobs on our receiving sets and tuning from one station to another that we may have forgotten that only a year ago all of the broadcasting stations were crowded on to two wave-lengths or frequencies. Now we have about 50 Class B stations, and each of these, so far as they operate simultaneously, has it own frequency. We have listened to broadcasting of Presidential addresses and other notable events, when a number of radio stations were connected by wire line with one another. The extension of such an arrangement, either by wire connecting lines between broadcasting stations over the country or by using radio itself as the connecting mechanism, will bring a unity of thought in this country which could scarcely be imagined otherwise. Some day we will probably see as well as listen, though first of all in lecture halls or auditoriums, on account of the expense.

We are now able to go to a radio store and select receiving sets from a large and varied stock suited for every purse and for every purpose—the range running from crystal through reflex to neutrodyne and super-heterodyne.

Legal Aspects

In spite of the developments which have taken place, there are still many uncertainties in radio. One of these hangs on the control of the fundamental patents necessary for the operation of radio stations. Our patent laws grant a monopoly to every inventor, but whether this right is used in a way which restricts or restrains trade is a question which is now before the

Federal Trade Commission for investigation. Our copyright laws now have their effect on radio broadcasting. Many of those who have copyrights covering songs or other musical compositions feel that broadcasting stations should not permit these selections to be transmitted without paying a royalty to the owners.

Something for Nothing

Broadcasting is on a peculiar economic foundation. The public is certainly coming much closer now to getting something for nothing than ever before in history. One buys a radio receiving set and merely has to turn the knob to get a wide selection of programs, and in thought to travel from one part of the country to another. He is really a very fortunate man. It is as though one bought a phonograph and always thereafter got free from the manufacturer all the new records and had merely to purchase needles; or as though an automobile owner could get free gas and oil from the manufacturer of his machine and would only have to buy tires or, as though having wired our homes for electricity, we would expect to get free power from the electric light company and merely have to purchase new bulbs from time to time. Somebody, of course, pays the cost of running the broadcasting stations. I do not believe payment for these programs can ever come directly from the owners of receiving sets. The tax which has recently been proposed in Congress is not for this purpose; it is a revenue tax for the United States Government. The fact that 570 broadcasting stations are operating in this country demonstrates that someone is willing to pay for their operation. Considering it very broadly, the owners of these broadcasting stations are really advertisers and are paying the cost as part of their advertising expense. It is no wonder that they are willing to pay in order to have an audience of 10 to 20 million people every night. I doubt whether the broadcasting will stop even when the artists and other talent who are giving the performances decide that the time has come to pay them for their services.

There are, I believe, two fundamentals in radio broadcasting on which its permanence as a part of our everyday life depends. One of these is the service which broadcasting brings to those who listen. The other is the power of broadcasting as an advertising or propaganda medium. The hope of safety in the latter respect is in the diversification of the control and ownership of transmitting stations. The listeners, too, can readily control the attention of the audience. The service rendered by radio is demonstrated by the thousands of letters received by the large broadcasting stations, the most appealing ones being from the country places and from shut-ins. And I am sure that this service will develop to limits which are as yet undreamed of.

TRANSMISSION OF WEATHER REPORTS BY NAVAL RADIO STATIONS

Through co-operation with local offices of the United States Weather Bureau, weather forecasts are sent broadcast to sea through naval coast radio stations at certain times, varying with the locality, as described below. Coast stations are generally prepared to give local forecasts to passing vessels, without charge, on request.

Atlantic Coast

Sent by Washington (NAA) on 2,500 meters wave length and Key West (NAR) on 1,500 meters wave length immediately following 10 p. m. time and hydrographic information (seventy-fifth meridian time).

The coast line is divided as follows:

North Atlantic, Halifax to New York; middle Atlantic, New York to Hatteras; south Atlantic, Hatteras to Key West; east Gulf, Key West to mouth of Mississippi; west Gulf, mouth of Mississippi to mouth of Rio Grande.

This bulletin consists of two parts, the first part containing code letters and figures expressing the actual weather conditions at 8 p. m., seventy-fifth meridian time, on the day of distribution at certain points along the eastern coast of North America, one point along the coast of the Gulf of Mexico, and one at Bermuda. The second part contains a special forecast of the probable winds to be experienced a hundred miles or so offshore. The second part of the bulletin also contains certain warnings of severe storms along the coast whenever occasion arises.

The points for which weather conditions are furnished by the above bulletin are designated respectively by their initial letter, except in the case of Nantucket, for which the letter T is used; accordingly, S = Sydney, T = Nantucket, DB = Delaware Breakwater, H = Hatteras, C = Charleston, K = Key West, P = Pensacola, and B = Bermuda.

Great Lakes

Sent by Great Lakes (NAJ) on 1,512 meters and Washington (NAA) on 2,500 meters immediately following 10 p. m. time and hydrographic information (ninetieth meridian time).

This bulletin is sent in a similar manner to the one sent out for the Atlantic coast, except the first part expresses the actual weather conditions at 7 p. m., ninetieth meridian time, on the day of distribution at certain points on the Great Lakes. These points are designated as follows: Du = Duluth, M = Marquette, U = Sault Sainte Marie, G = Green Bay, Ch = Chicago,

L = Alpena, D = Detroit, V = Cleveland, and F = Buffalo.

This grouping begins on Lake Superior and ends on Lake Erie.

The second part contains a special forecast of the probable winds to be experienced on the lakes.

Lakes Superior, Michigan, and Huron are considered the upper lakes, and Lakes Erie and Ontario the lower lakes.

All bulletins begin with the letters U. S. W. B. (United States Weather Bureau) and the weather conditions follow. The first three figures of a report represent the barometric pressure in inches (002 = 30.02); the next figure, the fourth in sequence, represents the direction of the wind to the eight points of the compass: 1 = north, 2 = northeast, 3 = east, 4 = southeast, 5 = south, 6 = southwest, 7 = west, 8 = northwest, and 0 = calm. The fifth figure represents the force of the wind on the Beaufort scale following.:

Beaufort Scale of Wind Force

Number and Designation	Statute Miles per per Hour	Nautical Miles per per Hour
0 Calm	0 to 3	0 to 2.6
1 Light air	8	6.9
2 Light breeze	13	11.3
3 Gentle breeze	18	15.6
4 Moderate breeze	23	20.0
5 Fresh breeze	28	24.3
6 Strong breeze	34	29.5
7 Moderate gale	40	34.7
8 Fresh gale	48	41.6
9 Strong gale	56	48.6
10 Whole gale	65	56.4
11 Storm	75	65.1
12 Hurricane	90 and over	78.1 and over

In order to simplify the code, no provision has been made for wind force greater than 9, strong gale, on the Beaufort scale. Whenever winds of force greater than 9 occur, the number representing them is given in words instead of figures, thus: Ten, eleven, etc.

Example of Code

U S W B S 96465 T 91674 DB 94686 H 99886 C 01214 K 02622 P 03613 B 00065.

Translation

United States Weather Bureau.

Station	Pressure	Wind Direction	Wind Force[1]
Sydney	29.64	SW	5
Nantucket	29.16	W	4
Delaware Breakwater	29.46	NW	6
Hatteras	29.98	NW	6
Charleston	30.12	N	4
Key West	30.26	NE	2
Pensacola	30.36	N	3
Bermuda	30.00	SW	5

[1] See Beaufort scale.

Pacific Coast

Weather bulletins are obtained from the Weather Bureau, San Francisco, by the San Francisco Naval Radio Station at about 8.30 a. m. and 6 p. m. and forwarded by radio to North Head and San Diego as soon as practicable. Same is broadcast by San Francisco, North Head, and San Diego at noon and 10 p. m. on 952 meters immediately after transmission of time signals. Hydrographic information and storm warnings are broadcast immediately upon receipt by Tatoosh, Puget Sound, North Head, Marshfield, San Francisco, and Point Arguello on 600 and 952 meters in succession, and also after broadcasting local weather report. Local weather reports broadcast by Tatoosh, North Head, San Francisco, and San Diego at 8 a. m. and 4 p. m. on 600 meters and at noon and 10 p. m. 952 meters; and at noon and 10 p. m. by Puget Sound, Marshfield, and Point Arguello on 600 meters. Total weather report from Farallones Islands is forwarded to San Francisco for Marine Exchange at 8 a. m., noon, and 5 p. m.

The daily bulletin broadcast by San Francisco, North Head, and San Diego will consist of two parts. The first part will contain code words and figures which will express the actual weather conditions at 5 p. m. (one hundred and twentieth meridian time) on the day of distribution at certain points along the western coast of the United States. The second part of the bulletin will contain a special forecast of the probable winds to be experienced a hundred miles or so offshore, made by the United States Weather Bureau, San Francisco, for distribution to shipmasters by naval radio as above. The second part of the bulletin will also contain warnings of severe storms along the coast as occasion may arise.

The points on the Pacific coast from which weather conditions will be furnished will be designated, respectively, by their initial letter:

T = Tatoosh. NH = North Head. E = Eureka. SF = San Francisco. SD = San Diego.

The bulletin will begin with the letters "U S W B S F," signifying United States Weather Bureau, San Francisco, and the weather conditions will follow.

If the weather conditions for any station cannot be supplied, the initial of the station will be given, followed by the word "Missing;" and if any portion of a report cannot be furnished, such portion will be replaced by an equivalent number of letters, X.

The coast line of the western part of the United States will be divided as follows:

Northern Pacific, Tatoosh to Cape Blanco.

Central Pacific, Cape Blanco to Point Arguello.

Southern Pacific, Point Arguello to San Diego.

The forecast will be in ordinary language and will cover a period of 24 hours from 5 p. m., date of issue.

TRANSMISSION OF TIME SIGNALS BY NAVAL RADIO STATIONS

The transmission of time signals to vessels at sea by means of radio-telegraphy was first accomplished in the United States in 1905, and this service, enlarged and extended, has continued to the present time. This service is of the greatest value to mariners, as it furnishes a means by which the time, as given by the transmitted signals, may be compared with a ship's chronometer and the error of the chronometer found. Similar comparisons over a number of days enable data to be obtained by which not only the error may be found but also the chronometer rate; that is, the rate at which it is gaining or losing.

The noontime signals on the Atlantic coast are sent out through the coast radio stations by connection with Western Union telegraph lines from the United States Naval Observatory at Washington, D. C. By the operation of proper relays in electrical circuits, the beats of the seconds of a standard clock in the observatory are sent out broadcast as a series of radio dots, commencing five minutes before the time of the final signal. By omitting certain dots in a series, the comparison between the dots and the beats of the chronometer seconds can be checked until the instant of local noon (seventy-fifth meridian time) is reached. This is marked by a longer dot, which gives the time of exact noon. A comparison with the chronometer time at that instant gives its error referred to the seventy-fifth meridian time. Applying the difference in longitude, namely, five hours, between the seventy-fifth meridian and Greenwich, which is the standard meridian (or 0° longitude), the error of the chronometer referred to Greenwich time is determined.

Stations Transmitting Time Signals.

Station	Call Letters	Wave Length	When Sent
		Meters	
Washington	NAA	[1]2,500	11.55 a. m. and 9.55 p. m., std. time, 75th meridian.
Annapolis	NSS	[2]17,000	
Key West	NAR	[1]1,500	11.55 a. m. std. time, 75th mer.
New Orleans	NAT	[1]1,000	
Balboa, Panama	NBA	[2]7,000	1.55 a. m., and 12.55 p. m., std. time, 75th meridian.
Colon, Panama	NAX	[1]1,500	
Cavite, P. I.	NPO	1952 [2]5,000	10.55 a m., and 9.55 p. m., std. time, 120th meridian, east.
North Head, Wash.	NPE	[1]2,800	11.55 a.m. std. time, 120th meridian, west.
Eureka, Calif.	NPW	[1]2,000	
Point Arguello, Calif.	NPK	[1]1,512	Daily at 11.55 a. m., td. time, 120th meridian, west.
San Diego, Calif.	NPL	[2]9,800 [1]2,400	
San Francisco, Calif.	NPH	[2]4,800 [1]2,400	11.55 a. m., std. time, 120th meridian, west.
Great Lakes, Ill.	NAJ	[1]1,512	Daily except Sundays and holidays at 10.55 a.m. std. time, 90th mer.
Pearl Harbor, Hawaii	NPM	[2]11,200 [1]600	180th meridian, mean noon.

[1]Spark. [2]Arc.

WHY DO SIGNALS FADE?

One of the greatest difficulties encountered in radio communication at very high wave frequencies, or short wave lengths, is the so-called "fading" or "swinging" of the received signals. Fading is a rapid variation of intensity of the signals received from a transmitting station, all circuit adjustments at the transmitting and receiving stations remaining constant.

What is Fading?

As a typical example of fading, suppose that a radio laboratory at Washington were listening to a station in Massachusetts. This station may call and be received with satisfactory intensity, may begin the preamble of the message, and then, as the text is begun, the signals may rapidly increase in intensity, until within a few seconds they may be heard throughout an ordinary room. Then the signals may become rapidly weaker until they are unreadable or even inaudible by the time the end of the message is reached. By the time the station has finished the transmission of the message, the signals may again be received at a satisfactory intensity. It can be seen that this makes communication very difficult, and may occasion many repetitions of transmissions which, if the maximum intensity were maintained, could be received without difficulty at the first attempt.

Fading is much more pronounced on the shorter wave lengths, and, in fact, there is little fading on wave lengths greater than 400 meters. When fading does occur on these longer wave lengths, the variations are much less in amplitude and far less erratic than those which occur on the shorter wave lengths. Fading does not ordinarily take place within the daylight or reliable range of the transmitting station. It is primarily a phenomenon noted at long distances from the transmitter, and hence is more prevalent during the night time, when transmission ranges are greatest.

Ionization of Atmosphere

It is well known that ultra-violet light has the power of ionizing gaseous molecules or separating from them electrons. Hence, since the sun's ultra-violet light is largely absorbed in the upper atmosphere, it may well be that the portion of the earth's atmosphere which is facing the sun will have present in it more electrons or gaseous ions than that portion which is turned toward the earth, and it may therefore be less transparent to radio waves. In other words, clear, sunlit air, though extremely transparent to light waves, may act as if it were a slightly turbid medium for radio waves. The dividing line between that portion of the earth's atmosphere which is impregnated with gaseous ions or elec-

trons, is not sharply defined from the portion which contains few ions, and there may therefore be considerable penetration of these ions into the regions which may be called the twilight areas. When electromagnetic waves are propagated into regions containing many free electrons, much of the energy in the waves will be given up to these electrons in causing them to move in space in the direction of the wave. Evidently the greater the number of these electrons in the space through which the waves pass, the greater will be the absorption of energy from the waves.

Bending of Radio Waves

There is another point which it is necessary to explain here for the purpose of completing the explanation. It is generally believed that light waves cast a sharp shadow behind an obstruction. This is not exactly true if the obstruction is of the same order of magnitude as the length of the light ray. Huygens has shown that a slight illumination may occur in the geometrical shadow when, as in Figure 1, an opaque screen is so placed as to cut off half the light wave. S is supposed to be a point-source of light, radiating light waves in all directions. The obstacle is placed so as to cut off half the waves. The geometrical shadow is the region to the right of the obstacle and below the line SO. It actually happens, however, that if we place a screen at O, it will be feebly illuminated as far down as the point D. Accordingly, in the case of light waves there is an illumination which extends slightly within the boundary of the geometrical shadow, but fading off, and, in any case, very small. On the other hand, if we are dealing with long electric waves, or with sound waves of which the wave length is not small compared with the distances from S and O to the obstruction then this bending around or diffraction is very sensible, and there is no sharply defined edge to the shadow. In the case of radio-telegraphic electric waves 300 meters or more in length, natural objects, such as cliffs or hills, do cast what may be called electromagnetic shadows; but the longer the wave length which we employ, the less marked is the effect.

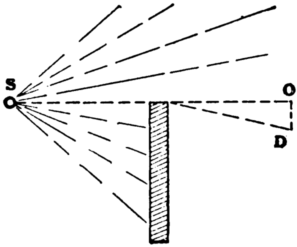

Fig. 1

Although this explanation may account for the bending of radio waves around the earth for some distance, it has been shown that the actual amount of bending of long electric waves around the earth for a range of 45° of longitude is greater than can be accounted for by true diffraction. This conclusion was

arrived at analytically by Dr. J. W. Nicholson, in 1910, who considers that other causes, such as reflection from a layer of ionized air at high altitudes, must be sought for as an aid to diffraction in explaining this abnormal bending. It may be said that there is something of the nature of a reversed mirage effect, by virtue of which the waves are deflected around the earth by the reflective action of highly ionized layers of air in the upper atmosphere.

The Heaviside Layer

This layer of highly ionized air is the so-called "Heaviside layer," the explanation of which is due to Oliver Heaviside, in 1910.

The idea of an upper conducting surface between which and the earth's surface electrical waves would be propagated antedates the use of radio for long-distance communication, since it was discovered by Fitzgerald in 1893 and by Heaviside in 1900. Considerations largely independent of radio phenomena suggest the following structure and boundaries of the atmosphere, as indicated in Figure 2. (*a*) The earth's surface, a relatively

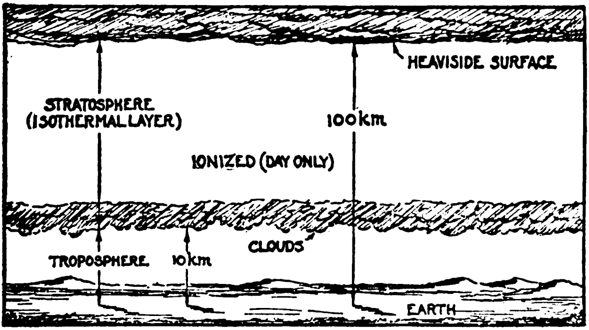

Fig. 2

poor conductor. (*b*) The troposphere, about 6 miles thick, within which are the causes of our meteorological phenomena, and an atmosphere similar to that which we breathe. (*c*) A radioactive layer, separating the troposphere from the region above it. (The existence of this layer is not as well established as the others, nor is its existence so important in the explanation of the radio phenomena. (*d*) The stratosphere, or isothermal layer, having a thickness of approximately 60 miles. The stratosphere is ionized by the sun's rays in the daytime, but quickly loses this property by the recombination of the ions at night. (*e*) The Heaviside surface, permanently ionized, and an almost perfect conductor.

The boundary of the Heaviside surface changes from time to time. The permanently ionized region above

the Heaviside surface is so good a conductor that waves cannot penetrate it. Any waves reaching it can only slide along it, just as waves slide along the even less perfectly conducting surface of the earth.

In daylight transmission the waves cannot reach the Heaviside surface because of the intervening stratosphere ionized by the sunlight, and hence only those waves which travel along the earth's surface are useful during the daytime. In traveling along the earth's surface the waves are diminished in intensity by absorption of their energy in the earth. At night, on the other hand, the waves may reach the Heaviside surface and travel and slide along it without appreciable absorption.

Occurrence of Fading

Observations indicate that the fading is greatest for a certain range of wave lengths and is less for either longer or shorter waves. Fading is more pronounced at wave lengths in the neighborhood of 250 meters than at longer wave lengths. Experiments using 100-meter wave indicate less severe fading than on 250 meters. This may give an indication of the magnitude of the irregularities of the Heaviside surface.

On a wave length between 350 and 400 meters, the intensity of signals received at night was found to vary between two definite limiting values. These values are: (1) That which would be obtained if the waves suffered no absorption, and (2) that which would be obtained with the absorption normally present in daytime transmission.

That is, the part of the wave which travels up to the Heaviside surface may be unabsorbed, or it may be totally absorbed, leaving, in the latter case, only the wave conducted along the ground as effective in transmitting signals.

Within the distance from a transmitting station in which ground absorption is negligible there is no fading, and the day and night intensities are equal, since the waves are not affected by conditions in the upper atmosphere.

A study of the transmission range of certain broadcasting stations indicates that at a distance of the order of 150 miles from the transmitting station a noticeable decrease is observed in the signal intensity, which increases again for greater distances. The distance at which this occurs varies with the wave frequency, which suggests that its explanation is associated with the variation of ground absorption with wave frequency, and that the signals received at distances beyond this minimum point are due to the propagation along the Heaviside surface.

CHAPTER TWO

HOW TO RECEIVE RADIO

As explained in chapters 1 and 4, radio may be either telephony or telegraphy, that is, one may hear the actual voice of the person who is speaking into a radio telephone transmitting set, or one may hear the long and short buzzing sound constituting the dots and dashes of the telegraph code. Fortunately the same receiving apparatus may be used to receive either telephony or telegraphy, except for the special kind of radio telegraph signals which are called continuous wave signals and usually spoken of as "C W" Special equipment described in Chap. 5 is required for this purpose.

While the law requires that one must have a license from the United States Department of Commerce in order to operate a radio telegraph or radio telephone transmitting station*, there is no requirement whatever regarding the operation of a radio receiving station. It would obviously be impossible to determine where all the receiving stations are located, now that antennas can be installed indoors, or to enforce any law requireing that they be licensed unless the receiving stations also did some transmitting. It happens that certain kinds of receiving apparatus, which will be described later, do behave as very weak radio transmitting sets and so may be heard by any other nearby receiving station. It is likely that fewer of the receiving sets, which can also act as feeble transmitting sets, will be sold in the future, but often those which are now in use can be so adjusted in their operation as to avoid their doing any transmitting. This is desirable in order that they may cause no trouble to other persons who are trying to receive radio from a distance.

Essential Parts of a Receiving Station.—The connections between the essential parts of the simplest type of receiving station are shown in Fig. 1. The principal apparatus is the "receiving set." Its main connections are to the "antenna" and to the "ground." The received signals come into the receiving set through these connections. In the receiving set they are converted into an electric current which produces the

*Information regarding licenses for radio transmitting stations and operators may be obtained from a pamphlet, "Radio Communication Laws of the United States," which may be purchased for 15 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

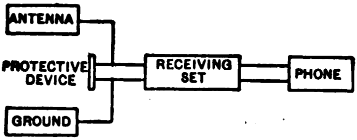

Fig. 1—Essential Connections of a Receiving Station.

sound in the "phone." The phone is either a pair of telephone receivers worn on the head of the listener or else a loud-speaking telephone receiver which can be heard all over the room. The received signals will not be powerful enough to operate a loud-speaking telephone receiver with the simpler types of sets unless the signals come from a powerful transmitting station not more than a few miles away.

The "receiving set" is subdivided into "tuner" and "detector," as shown in Fig. 2.

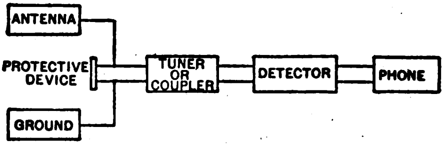

Fig. 2—More Detailed Connections of a Simple Type of Receiving Station.

Selection of Receiving Set for a Given Purpose.—The selection of a radio receiving set depends on a number of factors which should be pretty well in the mind of the user before he purchases or constructs his station. First among these are the wave length and the distance to the radio transmitting station or stations which he desires to hear. If only the reception of the short-wave broadcasting stations is desired there is no need of securing a set which will receive both short and long waves. In addition the user must decide whether he will be content to receive signals which are just audible when the telephone receivers are held tightly against his ears or whether he desires to have signals so loud as to be heard through an entire room. He must also decide whether he is willing to pay for a receiving set which is nicely finished in appearance, or whether he is content to have a more ordinary looking set. Obviously the more he demands from his receiving set the more he will have to pay for it. An additional feature which it is desirable for the listener to know is the power of the transmitting station which it is desired to hear. This can be determined by reference to the map in the appendix.

One must not be misled into thinking that very simple apparatus can accomplish great results just because of reports of very long distances over which radio has been received on some occasions. These

extraordinarily long distances are usually obtained at night and are very irregular. If one expects to make the fullest use of his radio station he must plan to put in a station which will be sure to receive regularly the service which he desires. He will then receive as extra service the more distant stations which may be heard when transmission conditions are favorable. It must

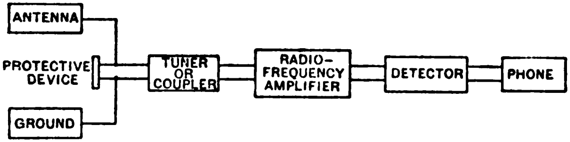

Fig. 3—Essential Connections of Receiving Station with Radio-Frequency Amplifier.

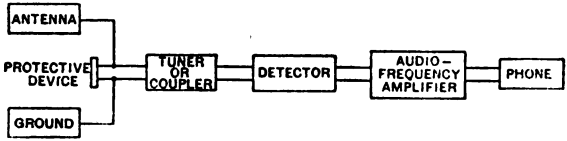

Fig. 4—Essential Connections of Receiving Station with Audio-Frequency Amplifier.

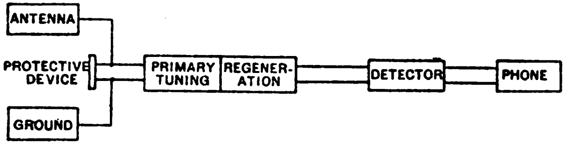

Fig. 5—Essential Connections and Controls of Receiving Station with Single-Circuit Regenerative Receiving Set.

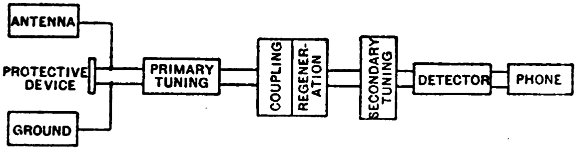

Fig. 6—Essential Connections and Controls of Receiving Station with Two-Circuit Regenerative Receiving Set.

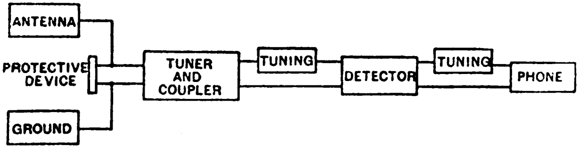

Fig. 7—Essential Connections and Controls of Receiving Station with Three-Circuit Regenerative Receiving Set.

also be emphasized that radio carries much farther at night than in the day time. This is especially noticeable at a distance of fifty miles or more from the transmitting station. For reliable radio service in the day time one must, therefore, have much better radio receiving apparatus than is necessary for reliable service at night. While very much depends upon the design of the particular type of receiving set which is used, it is believed that Table 1 may be used as a guide in determining the general type of receiving set which should be purchased in order to get reliable radio service from certain distances in the day time.

Table 1.—Showing approximate distances in miles for reliable day-time radio telephone receiving

Intensity of Signals	From Transmitting Station having 50 watts in antenna			From transmitting station having 500 watts in antenna		
	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier
Readable signals in telephone receivers..	8	20	40	35	65	100
Loud signals in telephone receivers.....	1	8	20	5	35	65

Antenna and Ground System.—Many types of antenna are in general use. The particular type of antenna used and its construction will be usually determined by local conditions, such as the location of convenient high supports, the presence of large trees, and third the dimensions of the property. A good form of antenna for receiving from most of the radio telephone broadcasting stations consists of a single wire 75 or 100 feet long and about 30 feet above the ground. Descriptions of various kinds of antennas with detailed explanations regarding the proper methods of installing and directions for making the ground connections are given in chapter 3.

Tuner.—The tuner is the part of the radio receiving apparatus which is used to permit the signals from the desired station to be received while all other signals are kept out so far as possible. When it is set at the right point the signals come in much louder than for any other setting. Some tuners are more effective than others in giving a large ratio of signal strength between the wave to which the set is tuned and undesired waves. This ratio of signal strength is called the "selectivity," *i. e.* a set with large selectivity shuts out all waves, except the one to which it is tuned, more effectively than a set with small selectivity. The electric currents produced in the tuner are converted by the detect-

or into a form suitable for actuating the diaphragms of the telephone receivers. The knobs and handles which are located on the front of these tuners are for the purpose of changing the wave to which the apparatus is tuned, that is, the turning of these knobs results in tuning out a station which uses one wave and tuning in a station which uses another wave. In some of the types of tuners there is employed a special circuit for increasing the loudness of the signals even before they reach the detector. Such a circuit is called a regenerative circuit and for its adjustment one and sometimes two knobs are required.

Detector.—The detector used with a present day receiving set is ordinarily either a crystal detector or an electron tube detector. Either type of detector may be built into the same panel or box as the tuner. In some cases the detector is mounted on a separate stand or panel.

In the simplest sets the tuner is a single coil of wire with an arrangement for putting different amounts of wire in circuit. In more complicated sets the tuner includes a "coupler" and other parts. For further information on couplers see page 16 of this chapter.

The crystal detector usually consists of a fine wire or other metal point (sometimes called a cat whisker), resting lightly upon a small piece of galena (lead ore). All galena is not equally sensitive nor are all spots on a given crystal sensitive. When a crystal detector is used it is very desirable to employ a test buzzer with a dry battery to determine when the detector is adjusted to a sensitive condition. The use of the test buzzer is described under Preliminary Adjustments, page 9, chap. 2.

In adjusting a crystal detector the end of the fine wire is touched lightly to one spot of the crystal after another until the sound of the test buzzer or of the desired signals, or of atmospheric disturbances, is heard in the phone. The adjustment is difficult to maintain permanently and it is necessary to make sure each time the set is used that the wire is touching a sensitive spot on the crystal.

The electron tube detector has the advantage that it does not require special adjustment of a delicate contact to make it sensitive. Its sensitivity can be kept invariable and, it may also be much more sensitive than the ordinary crystal detector. The electron tube detector is sometimes called a vacuum tube, audion, or triode. This type of detector consists of an incandescent electric bulb very similar to an ordinary electric light bulb except that there are other parts sealed into it in addition to the heated filament. The filament is lighted by a battery called the "A" battery, usually a storage battery of about 6 volts though this depends upon the type of electron tube used. Another battery

is employed in connection with the electron tube. This is called the "B" battery and usually consists of a number of small dry cells sealed in a block as a unit.

The frontispiece shows a number of electron tubes of various types designed for use as detectors, amplifiers and transmitters. The more recently developed tubes which operate on dry batteries are smaller than the others and are convenient for use in small portable receiving sets. In Fig. 8 there can be seen the several

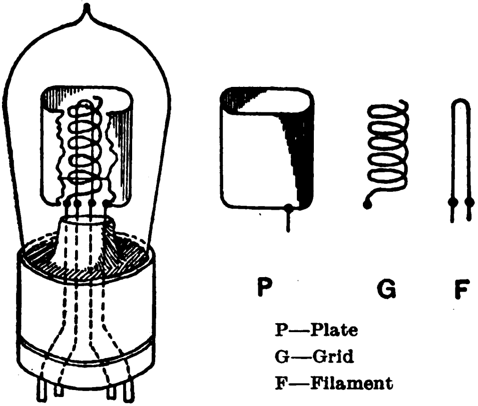

Fig. 8—Electron Tube

parts or elements of an electron tube. These are the filament, grid, and plate which are mounted inside of the glass tube from which the air has been pumped out. Each of these elements is separated from the other by a small space. There are two connections made to the filament, one at each of its ends. There is only one connection made to the grid and one connection to the plate. These four connections come to the four prongs on the base of the tube. The filament is surrounded by the grid, which is usually a spiral coil or lattice work. The plate is located outside of the grid and is usually cylindrical but sometimes flat.

The construction features of tubes used as amplifiers are identical to those of the detector tubes. They differ in the degree of vacuum produced within the bulb. The amplifiers have less air remaining in them.

Telephone Receivers.—The head sets or telephone receivers used for receiving radio are nearly the same as the standard telephone receiver which is very familiar. The principal difference is the form of construction. On account of the long periods of time for which radio head sets are often worn by an operator, these are made as light and as compact as possible and are therefore sometimes called watch case receivers. They

are mounted either singly or in pairs and are usually provided with a head band to hold them in place against the operator's ears. Telephone receivers designed for use with radio receiving sets usually have much more wire wound upon the magnets in order that a small current through the receiver may produce a louder sound from the diaphragm. As an indication of the amount of wire used in winding the telephone receiver magnets the receivers are ordinarily rated by the resistance of this winding. Thus some receivers are 1000 ohms and others 2000 or 3000 ohms. It is impossible, however, to judge the performance of a telephone receiver by resistance alone, since many other factors enter into the determination of its efficiency. The two receivers of the head set are usually connected in series.

Amplifiers.—The amplifier is a device employing one or more electron tubes in order to make the received radio signals louder than they would be without it. Many amplifiers have two or three electron tubes and are called "audio-frequency" amplifiers. The "audio-frequency" currents which are thus amplified are those which pulsate at a frequency which can be heard by the human ear, *i. e.*, ordinarily between 16 and 10,000 cycles per second. They correspond to the frequencies of sound waves produced by the voice and by musical instruments. They are connected between the detector and telephone receivers. There are also being manufactured amplifiers called "radio-frequency" amplifiers which are connected between the tuner and the detector. Radio-frequency amplifiers serve to amplify the currents of the tuner before they are connected to the detector. These two types of amplifiers are very similar in outward appearance. Since the amplifiers employ electron tubes, it is necessary to use batteries to light the filaments of these tubes as in the case of the detector tube referred to above. It is also necessary to use the small blocks of dry batteries in the plate circuits of these tubes, The connections of the amplifier and detector are ordinarily arranged to make possible the use of a single storage battery for lighting the filaments of all of the tubes and a single "B" battery for connection to the plate circuits of all of the tubes of a single receiving set. The voltage of the "B" battery may be anything between 40 and 100 volts. Somewhat louder signals are secured by using the higher voltages suggested. The detector tube, however, rarely requires a voltage over 22½.

Receiving sets are now on the market which utilize specially designed electron tubes requiring a comparatively small current to light the filaments. These tubes can be operated from dry batteries, unless there are several tubes in the same receiving set. In the latter case the total current required is great enough to make storage batteries more economical. Receiving

sets have been developed in which the filaments of the tubes are lighted from the commercial lighting circuit, but no one should attempt to improvise such a connection without expert advice. Until further improvements are effected, the storage battery will remain the most satisfactory means of operating the vacuum tubes.

Storage Battery.—A storage battery can be used with a radio receiving set for only a limited time without recharging. In order to recharge the battery and put it in condition to supply further current to the receiving apparatus, it is necessary to connect it through special apparatus with the power or lighting circuit or send it to an electrical shop to be charged. A number of devices are made for use in charging a small storage battery from the house lighting circuit. Some of these can be connected to an ordinary electric light socket and require very little attention. One must be sure to know by inquiring of his electric light company whether his lighting power is alternating or direct current. This makes an important difference in the type of battery charger which is suitable. When the battery is connected to the electric light circuit through the charger and the necessary initial adjustment of the charging current is made, it can ordinarily be left in this condition, that is, "on charge" for a number of hours without attention. The time of charge depends upon the capacity of the battery and the amount which it has been used since it was last charged. It is advisable to use a hydrometer as a tester in order to determine whether the battery needs recharging. It is not desirable to permit the battery to become so greatly discharged as to fail to light the filaments of the electron tubes to their normal brilliancy. Storage batteries need to have distilled water added to them at intervals. This can be secured at any automobile or battery service station. Detailed instructions for care and operation are furnished with each battery by the manufacturer.

Loud Speakers.—Loud speaking reproducers are on the market which can be substituted for the telephone receivers in any receiving set which employs an amplifier. The use of this loud speaker makes it possible to hear the radio signals throughout an ordinary room though the volume of this sound varies with different types of reproducers. Where exceptionally great volume of sound is required it is necessary to employ additional amplifiers in order to take the fullest advantage of the loud speaking equipment. There is the disadvantage, however, that when great amplification is used, especially with improperly designed equipment, there is a considerable amount of distortion and thus the quality of the speech is impaired. The clearness and distinctness of the signals will therefore in general

be best when received with head telephone receivers. However, a number of very satisfactory loud speakers are now on the market which, if not forced unreasonably, will give excellent results.

Manipulation of Receiving Sets.—In view of the differences of manipulation of the various types and makes of radio receiving sets, it is impossible to give a single general outline of procedure which can be followed with all sets, but a few general suggestions will be given for the handling of three specific types: (1) the single circuit; (2) the coupled circuit; (3) the three-circuit receiving set. This classification is based on the number of control handles which must be turned in tuning the receiving set to the wave length or frequency of the station which it is desired to hear. Complete operating instructions are furnished by the manufacturer with each set.

The parts of a single circuit receiving set are shown diagrammatically in Fig. 5. It may be seen here that there is but a single tuning element, though adjustments of other parts of the set must be made.

The coupled circuit receiving set is shown in Fig. 6 and the three-circuit receiving set in Fig. 7. The diagrams show how the several tuning elements are associated with the other parts of the set.

Preliminary Adjustments.—It is first necessary to make sure that the antenna is properly connected to the receiving set and that the ground connection is thoroughly made. In case an antenna switch is used, this should be thrown to the receiving position. Next the detector must be adjusted to a sensitive condition. In the case of a crystal detector this involves adjusting the contact of the fine wire or "cat whisker" until it touches a sensitive spot on the surface of the crystal. This can be determined by noting when the loudest sound is heard in the telephone receivers when the test buzzer is operated. If such a test buzzer is not included in the receiving set, a simple one can be connected as shown in Fig. 11. In case the detector is an electron tube it is necessary to light the filament by closing the filament switch. In some receiving sets this is done by the mere insertion of the telephone plug. The filament rheostat knob is then turned in the direction which increases the brilliancy of the filament until a slight hissing sound is heard in the telephone receivers. Then the rheostat handle is turned back very slightly to the point where this hissing is no longer heard. In case an electron tube amplifier is used, a slight adjustment of the current through the filaments of the amplifier tubes is also necessary.

Tuning to Broadcasting Stations.—The radio telephone broadcasting at the present time is on certain few wave lengths. Some of the transmitting stations are not tuned exactly to their nominal wave lengths but

deviate from them by about 5 or 10 meters. This means that when the receiving set has once been tuned to a given broadcasting station, only a slight readjustment of the tuning controls enables one to tune in any other broadcasting stations which are using wave lengths only slightly different from this but which are not too distant to be heard. If this fact is kept in mind the manipulation of the set is greatly simplified.

Tuning of Single-Circuit Receiving Set.—Some single circuit receiving sets have but a single tuning control in the form of a knob which is marked with a scale for reading its position. Other types of single circuit tuners have in addition a switch which can be turned to any one of several contact points. In either case the usual procedure is to carefully turn one or both knobs until a position is found where the desired signals are heard. On account of the sharp tuning of the radio telephone signals from distant stations it usually requires much more careful adjustment of the receiving circuits to receive speech or music than is required to receive signals from radio telegraph stations using spark transmitting sets. It is therefore desirable to move the continuously variable control knob rather slowly and listen carefully for a desired radio telephone station. In some receiving sets there is provided a small condenser called a "vernier" condenser which is used for the clearest final adjustment of the tuner. The position of the vernier condenser in a receiving set is given in the section on "Circuit Diagrams" below.

A "tickler" or "regenerative" control, if present, is operated as described on page 12 under "Adjustment of Regeneration."

Tuning of Two-Circuit Receiving Set.—The ordinary "coupled-circuit" or "two-circuit" tuner has three knobs or control handles. These are the primary-circuit tuning control, the secondary-circuit tuning control, and the coupling control. In the first tuning of a receiving station it is advisable to turn the coupling control knob to a point near the position marked "maximum." Then an approximate adjustment may be made of the primary circuit, after which the secondary-control is moved gradually over its entire range. If no signal is heard at any point, the primary control is moved slightly and the secondary control is again turned over its range. By repeating this process a point on both primary and secondary controls will be found where the desired signal is heard most clearly. Then the coupling knob is turned slightly in the direction toward "minimum" and the primary and secondary controls readjusted slightly in order to secure a louder signal. It will be found that the farther the coupling knob can be turned in the minimum direction the less will undesired stations be heard. It will also be found

possible to hear radio telephone signals with a much smaller or looser coupling than spark signals from stations of equal power. It will make the tuning of a coupled-circuit receiving set much easier if one has a chart or table giving the wave frequency or wave length to which the secondary circuit is tuned at each position of the secondary control knob. It will then be possible to set this knob at the position corresponding to the wave length of the desired station, and further adjustment of the primary circuit to this same wave length can be made much more quickly. A chart giving this wave length calibration of the secondary circuit can be made when the receiving set is manufactured. A similar chart can not be made for the primary circuit until after the receiving set is installed and connected to the antenna with which it is to be used, since the wave lengths corresponding to the various positions of the primary control knob depend to a great extent upon the size of the antenna employed.

If there is an additional control knob marked "tickler" or "regeneration" it should be kept in the minimum position until the tuning just described has been accomplished. It can then be adjusted as explained in the section on "Adjustment of Regeneration" on page 12.

Tuning of Three-Circuit Receiving Set.—The tuning of three-circuit receiving set is somewhat more complicated than that outlined above for single circuit and two-circuit receiving sets. In all there are five separate adjustments to be made. Adjustments of these must be changed in turn until the desired signals are received with the greatest intensity. These controls are as follows:

1. Primary circuit (marked on some sets "antenna inductance" or "antenna condenser").
2. Secondary circuit (sometimes marked "grid variometer").
3. Coupling.
4. Plate circuit (sometimes marked "plate variometer").
5. Detector (this is the same adjustment as the filament of the detector tube described under "Preliminary Adjustments.")

In tuning this receiving set the coupling control should be turned to approximately the middle point. A first approximate adjustment should then be made of the antenna inductance or antenna condenser control, setting them somewhat above the middle of the scale if the recommended antenna length of 75 to 100 feet is used. Using both hands rotate the grid variometer and plate variometer dials over their entire scales. These controls should be turned, one following the other, in such a way as to just keep the set from causing a slight hissing

sound in the telephone receivers. When, by successive adjustments of the primary control, the desired signal has been located at a given position of the grid variometer and plate variometer controls, the coupling knob should be turned toward the minimum position until the signal is just barely audible. The primary antenna inductance or antenna condenser control should then be turned to a point which just causes the cessation of the hissing sound in the telephone receivers. The final adjustment to give the loudest signals should be made on the coupling knob.

Adjustment of Regeneration.—In some receiving sets there is provided a control handle which is marked "regeneration" or "tickler." After the receiving set has been tuned to the desired signal the sound can usually be increased by turning the tickler knob from its minimum position until the speech or music begins to be distorted or until a whistling or sizzling sound is heard. The tickler control should then be turned back just below this critical point. In order to economize in the use of the storage battery for lighting the filaments of the detector and amplifier tubes, the filament brilliancy may then be slightly reduced while the tickler or regeneration control is gradually turned toward the maximum position. Since the loudness of the received signals increases greatly as the tickler or grid and plate variometer controls are brought close to the position which gives the hissing sound, it is desirable that these adjustments be made very accurately in order that the loudest sound possible may be obtained without the undesirable noise. It should also be remembered that when the tickler adjustment is turned beyond the hissing or whistling point, the receiving set is usually acting as a weak transmitting set and will cause interference for other receiving sets nearby. This condition should therefore be avoided.

Time spent in indiscriminate tuning and manipulation of the various controls will not produce nearly as satisfactory results as equal time spent in systematically making the tuning, coupling, and regenerative adjustments outlined above. The controls described are the principal ones, though some additional controls, such as vernier condenser, are provided on certain receiving sets for use in obtaining closer tuning adjustment. Such additional adjustments need not be made until the signals from the station desired have first been tuned in.

Detector and Amplifier Units.—Some manufacturers sell detector control panels or units mounted separately from the receiving set or tuner. Most amplifier units are also mounted on separate panels. The terminals of the detector or amplifier panels to which outside connections are to be made are usually clearly marked with the voltage of the battery which is to be

used and with the other necessary instructions. The terminals which are marked grid, filament, etc., and which are usually located at the left hand side of the detector panel should be connected to the corresponding terminals of the receiving set. In connecting the tuner, detector, and amplifier together, the wires used should be insulated, except of course at the ends, and should be as short as possible. In connecting the "A" and "B" batteries to the control panels, care should be taken to connect the positive terminals to the binding posts marked "positive" or "plus" and the negative terminals to the binding posts marked "negative" or "minus." The positive battery terminals are often colored red.

Loud-Speaking Reproducer.—If it is desired to use a loud speaking reproducer, or horn, this should be connected to the amplifier at the telephone terminals or through the plug which is ordinarily used for the telephone receivers. To secure exceedingly loud sounds a power amplifier using the larger types of tubes ordinarily employed in transmitting sets, should be used. Some types of loud speakers require the connection of a storage battery to a pair of additional binding posts located on the base of the loud speaker. It should be remembered that if additional amplifier tubes and loud speaking horns are to be connected to a common storage battery more frequent charging of the battery is necessary. The attachment of a horn to the telephone receivers regularly used with the receiving set is a help in throwing the sound out into the room. Attachments are on sale for clamping a telephone receiver to the horn of a phonograph in place of the reproducer.

Putting Receiving Sets Together.*—In case a person desires to construct his own radio receiving set he can purchase the parts and connect them together to form a set which may be as simple or as complicated as he desires. The accompanying circuit diagrams show

*It is assumed that the reader of this book does not wish to do more than to purchase the separate parts of a receiving set and put them together. The person who wishes to go still farther back and actually construct the parts of simple receiving sets is referred to an authoritative series of brief pamphlets now being put out by the U. S. Bu. of Standards. The first of these is Circular No. 120, "Construction and Operation of a Simple Homemade Radio Receiving Outfit," the second is Circular No. 121, "Construction and Operation of a Two-Circuit Radio Receiving Set." These are obtainable by mailing 5 cents for each to the Supt. of Documents, Govt. Printing Office, Washington, D. C. Later circulars in the series will describe auxiliary condensers, a loading coil to extend range to 3000 meters, an electron tube detector unit, and an electron tube amplifier unit. The issuance of these later circulars will be announced in the Radio Service Bulletin, a monthly publication of the Dept. of Commerce, a year's subscription to which may be obtained by sending 25 cents to the Supt. of Documents at above address. This bulletin contains each month all Government radio news.

the connections which should be made in order to assemble several typical receiving sets. The actual value of many of the coils or condensers required in the various circuits depends upon the wave length of the stations which it is desired to hear. The values given on the diagrams are correct for wave lengths of about 200 to 600 meters.

Inductance Coils.—The various circuit diagrams given in this chapter show inductance coils either as single coils, couplers, or "variometers." The following table is given as a guide in the selection of coils for use in the several circuits. It is not necessary to conform to the exact sizes stated, some variations of tuning being made possible by means of the variometers or variable condensers as well as by the taps provided on the coils. These sizes will be found suitable for tuning to 360 meter, 400, and 485 meter radio telephone stations which broadcast concerts, talks and market reports.

Table 2—Sizes of Inductance Coils for Tuning to Wave Lengths from 200 to 600 Meters.

Coil for single circuit tuner:

Diameter of tube.....4 inches
Length of tube.......5½ inches
Turns of wire........85, tapped at 25 turns and every 20 turns thereafter.
Size of wire..........No. 18 to 24 B. & S. gauge.
(If for non-regenerative circuit use no smaller than No. 20 wire.)

Coupler:—Dimensions given apply to "loose-couplers." (For variocoupler see 3rd table on page 15.)

Primary Tuning Coil

Diameter of tube.....4 inches
Length of tube.......5½ inches
Turns of wire........85, tapped at 12 turns and every 6 turns thereafter.
Size of wire..........No. 18 to 24 B. & S. gauge.

Secondary Tuning Coil

Diameter of tube.....3½ inches
Length of tube.......6 inches
Turns of wire........80, tapped at 20 turns and every 10 turns thereafter.
Size of wire..........No. 18 to 24 B. & S. gauge.
(If for non-regenerative circuit use no smaller than No 20 wire.)
The secondary coupling coil for a "3-circuit" receiving set should have about 30 turns of wire.

Variometer for antenna circuit of single-circuit receiving set:—

Fixed Coil or "Stator."

Diameter of coil......4 inches
Turns of wire........35
Size of wire..........No. 20 to 24 B. & S. gauge.

Moving Coil or "Rotor"

Diameter of coil......3½ inches
Turns of wire........30
Size of wire..........No. 20 to 24 B. & S. gauge.

Tickler coil:—

Diameter of tube.....3 inches
Lenght of tube.......2 inches
Turns of wire........30
Size of wire..........No. 24 to 30 B. & S. gauge.

Variometer for grid and plate circuits of 3-circuit receiving set or Variocoupler for 2-circuit receiving set:—

Fixed Coil or "Stator."

Diameter of coil......4½ inches
Turns of wire........65
Size of wire..........No. 20 to 24 B. & S. gauge.

Moving Coil or "Rotor."

Diameter of coil......3½ inches
Turns of wire........70
Size of wire..........No. 20 to 24 B. & S. gauge.

There are a number of types of inductance coils sold for use in building up receiving sets. These differ chiefly in the details of construction or winding and are variously called "single-layer," "bank wound," "honey comb," "spider web," "duolateral," etc., and are all of similar utility. Some coils are made so that the different sized ones are interchangeable on the set. They are frequently used as primary, secondary and tickler coils, the tuning adjustments being made by variable condensers.

Circuit Diagrams.—In the figures of this chapter the numbers shown on the condensers give suggested maximum values of capacity in microfarads which are correct for wave lengths of about 200 to 600 meters. Where the tuning condenser is connected across the inductance coil it is generally advisable to use a large inductance and small capacity to tune to a given wave length.

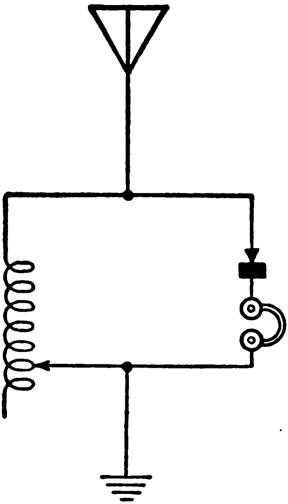

Fig. 9—Diagram of Simple Receiving Set using Crystal Detector.

Where a variable condenser (see symbols on page 33) is shown on these diagrams a condenser having a larger maximum capacity than indicated can be used, and when used with a given coil, makes it possible to tune the circuit to a wider range of wave lengths.

Fig. 9 shows a single-circuit receiving set using a crystal detector. Only one tuning adjustment is required with this set. This can be in the form of a switch or sliding contact for making connection at the desired point on the inductance coil.

Fig. 10 shows a two-circuit receiving set. The inductance coils L_1 and L_2 constitute the two coils of a coupler. There is no metallic connection between them. There are several forms of coupler: the "slide coupler," sometimes called a loose coupler, in which the coils are two cylinders wound with wire, one sliding within the other; the "variocoupler," in which one coil may be rotated within the other, and the "hinge coupler," in which the two coils are pivoted together like the two parts of a hinge.

The variable condenser C_1 is used for fine adjustment of the tuning of the secondary circuit. It is also convenient for tuning the circuit to different wave lengths. The longer the wave to which it is desired to tune the higher up one must go on the condenser scale, unless he simultaneously increases the number of turns of the inductance coil which are included in the circuit. It is usually best to use as much of the coil

as possible in tuning to a given wave length and do the close tuning with the condenser near the lower end of its scale.

The condenser C_2 is connected in series with the ground connection of the receiving set in case the antenna is somewhat longer than the ideal length for tuning to a given wave length. When connected in this way the condenser practically shortens the effective length of the antenna. The lower parts on its scale tunes the circuit to shorter waves, and when its capacity is made zero it corresponds to disconnecting the receiving set entirely from the ground.

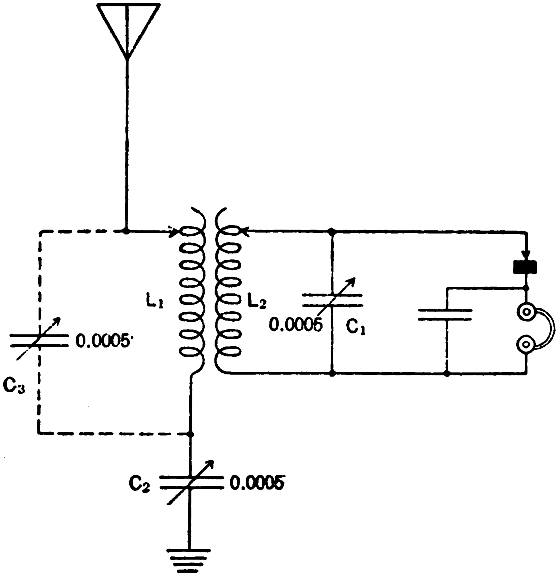

Fig. 10—Diagram of Two-Circuit Receiving Set using Crystal Detector.

In the case of a short antenna which it is desired to use in receiving from a longer-wave station the primary tuning condenser should be connected across the terminals of the inductance coil as shown by the dotted lines in Fig. 10, instead of in series with the coil. The end of the coil which is not connected to the antenna should then be connected directly to the ground. This parallel condenser gives the effect of lengthening the antenna so far as tuning is concerned and is also useful in making the final, close tuning adjustment.

The fixed condenser connected across the telephone receivers is called a "telephone condenser." Its size

is not ordinarily of much importance. Its effectiveness may depend upon the make of telephone receivers used and in some cases the use of such a condenser decreases rather than increases the strength of the received signals. Where it is useful at all a condenser of about 0.002 microfarad will usually be found quite satisfactory. It may be particularly effective in the case of reception from spark transmitting stations having low spark notes. Its utility can only be determined by trial.

The "vernier" condenser used for securing very fine adjustment of the tuning of a circuit, is a very small variable condenser connected across the terminals of a larger condenser so that a substantial change in the position of the control knob causes only a small change in the condenser capacity.

Testing the Detector Adjustment.—In order to determine when the crystal detector is adjusted to a sensitive position it is desirable to use a test buzzer. The position of the contact point on the crystal should be adjusted until the loudest sound of the buzzer is heard in the telephone receivers. The circuit for connecting this buzzer with a battery and by a single wire to the ground connection of the receiving set is shown in Fig. 11.

Electron Tube Detector.—A circuit using an electron tube detector in place of a crystal detector is shown in Fig. 12. It will be noted that this circuit is very similar to that of Fig. 10 and that the electron tube can readily be substituted for the crystal detector. One must take pains to secure a filament ("A") battery and plate ("B") battery which are suitable for the type of electron tube which is used. Most of the detector tubes

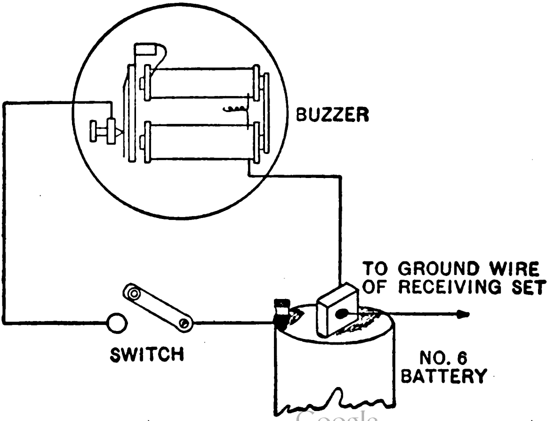

Fig. 11—Test Buzzer Circuit.

now on the market require a 6-volt storage battery and a 22½-volt plate battery. It is very desirable, however, to employ a plate battery which is adjustable by means of taps which are brought out from a number of

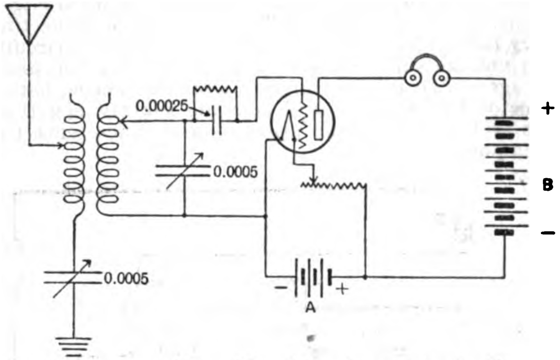

Fig. 12—Diagram of Two-Circuit Receiving Set using Electron Tube Detector.

the cells which form the complete battery. A rheostat is used in the filament battery circuit for adjusting the filament temperature to the best value.

Instead of the usual sliding contact rheostat a "ballast" lamp may be used which requires no adjustment. This is a fine wire of iron or other material enclosed in an evacuated glass tube. If the voltage of the "A" battery is slightly higher than normal, this wire tends to become heated and its resistance increased, the current thus being kept from rising to an excessive value. If the voltage of the "A" battery is below normal, the cooler wire offers less resistance, and approximately the same current is permitted to flow through the filament of the electron tube.

The connections which are made from various parts of the circuit to the filament, grid and plate of the electron tube are made by means of a socket. The wire connections can be soldered to the terminals forming a part of this base or socket, and care should be taken to make these connections to the proper terminals. A tube can be fastened into its socket by pushing it in as far as it will go and giving it a slight turn to the right. It is very desirable to use an ammeter in series with the filament and the "A" battery, in order to tell the exact amount of current which is flowing through the filament and to secure again the best adjustment when this has once been found. It is also an insurance against burning out the filament, which may result from carelessly heating the filament to an excessively high temperature by letting too much current flow through it.

It is sometimes desirable to maintain the grid of an electron tube at a definite voltage above the negative terminal of the filament, so that the tube will operate with the maximum effectiveness as a detector or as an amplifier in a specific case. This may be done either by means of the "stabilizer" rheostat or by connecting a dry battery of a few volts in series in the grid circuit. The voltage supplied is sometimes called a "biasing" voltage. The tubes ordinarily available act as better detector tubes if the grid is made slightly negative. The grid condenser and grid leak resistance serve the same purpose.

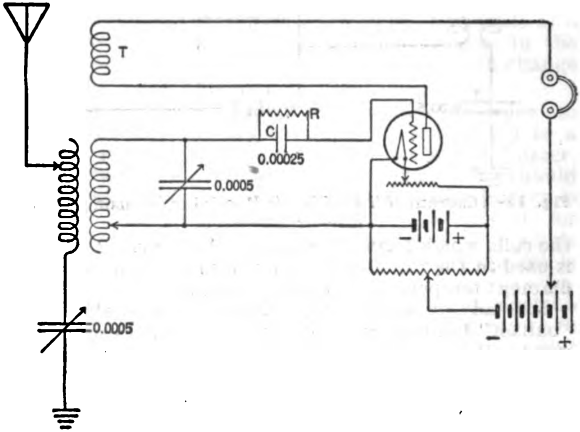

Fig. 13—Diagram of Two-Circuit Regenerative Receiving Set using Electron Tube Detector.

Tickler Coil.—Another receiving circuit using a single electron tube detector is shown in Fig. 13. This circuit makes use of a tickler coil, T, which is placed close to the secondary inductance and which is effective in increasing the loudness of the received signals. The tickler coil may be the rotor of variocoupler, or may be wound on a cylinder and so arranged as to slide within or over the secondary coil. It is also satisfactory to use flat coils, such as the "honeycomb," so arranged that the tickler coil is placed alongside the secondary coil. A small condenser C and "grid leak" resistance R are connected between the tuned circuit and the grid of the tube. A grid leak resistance of 1 or 2 megohms shunted across a condenser having a capacity of 0.00025 microfarads is ordinarily satisfactory, though the best values depend upon the particular type of detector tube employed. This circuit is very selective as well as quite sensitive and is not so likely as is the next circuit described to cause very great difficulty to nearby receiving sets by acting as a feeble transmitting set.

The resistance which is connected across the "A" battery in Fig. 13 is a potentiometer resistance or "stabilizer" of approximately 200 ohms. The sliding contact on this resistance makes it possible to obtain finer adjustment of the voltage in the plate circuit. In some circuits, as at R, in Fig. 18, a similar resistance is used to secure adjustment of the voltage between the grid and the filament. If the variations of voltage are obtained by direct connection to the individual cells of the battery it is impossible to adjust more closely than by steps of one or two volts. By using the potentiometer resistance, with its continuously variable contact, much finer variation is obtainable. This potentiometer resistance or stabilizer itself draws some current from the battery across which it is connected but the amount is small if the resistance of the potentiometer is large. This follows from the principle stated in Chap. 4 that the current is equal to the voltage divided by the resistance. It is well to entirely disconnect one end of the battery itself when the receiving set is not in use in order to avoid unnecessary waste of current.

A somewhat simpler circuit, which has the main features of that shown in Fig. 9 but which is regenerative and employs an electron tube detector and which is therefore more sensitive and selective, is shown in Fig 14. The primary inductance P and the tickler coil T may be the two windings of a variocoupler. If the set fails to regenerate or to generate, the connections to the tickler coil should be reversed, since the coupling between the tickler and the tuning inductance must be in the proper direction. If this cir-

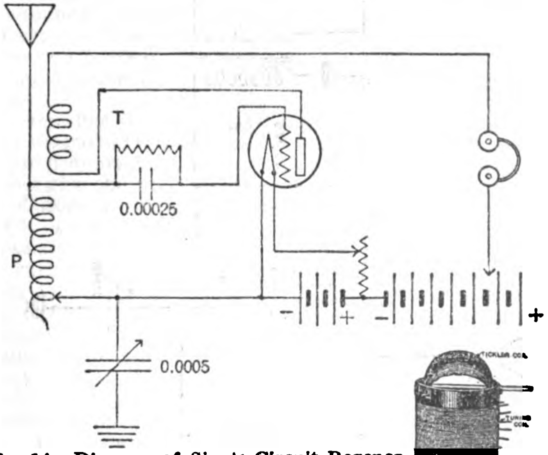

Fig. 14—Diagram of Single-Circuit Regenerative Receiving Set using Electron Tube Detector.

cult is adjusted to the generating (oscillating) condition it may become a very troublesome source of interference to near-by receiving stations.

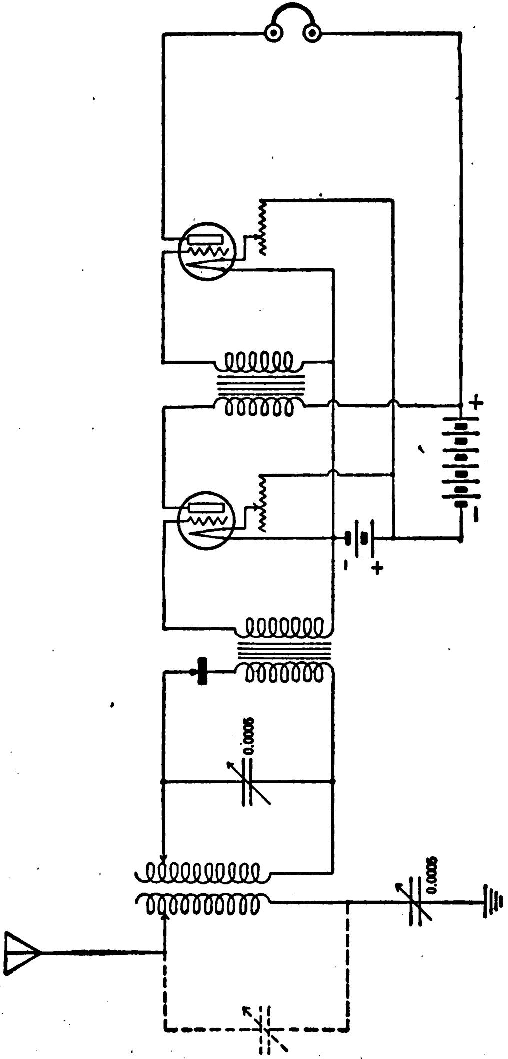

Fig. 15—Diagram of Crystal-Detector Receiving Set with Two-Stage Audio-Frequency Amplifier.

Amplifier Circuits.—A circuit which shows the method of connecting two amplifier tubes to a receiving circuit using a crystal detector is shown in Fig. 15. It is simply Fig. 10 with the telephone receivers (and their parallel condenser) replaced by the amplifier tubes and their accessories. It is more customary to use an electron tube as a detector in receiving sets having amplifiers. The use of a crystal detector, however, eliminates the cost of one tube and gives the advantage of simplicity which the crystal detector possesses.

Fig. 16 shows a set having an electron tube detector, with two amplifier tubes added. The principal change made from the circuit of Fig. 13 is the replacement of the telephone receivers by the transformer which connects to the first amplifier tube. After the desired number of amplifier tubes and intermediate transformers have been connected, the telephone receivers are then put into the plate circuit of the last amplifier tube. Unless very special precautions are taken to shield the transformers and the connecting wires of the amplifier, it is almost impossible to employ more than three amplifier tubes connected after the detector tube without causing a howling sound in the telephone receiver which makes the reception of signals impossible. In general, by placing the transformers as far as six inches apart, and placing the cores of the transformers at right angles, the trouble will be minimized. The connecting of a condenser across the terminals of the primary winding of the first transformer of an audio-frequency amplifier will sometimes increase the strength of received signals as well as reduce the likelihood of the occurrence of this "howling." A condenser having a capacity of 0.005 microfarad is suitable for this purpose.

Amplifier tubes should be used in such a way that the magnitude of the output voltage always bears the same proportion to the magnitude of the input voltage, otherwise the quality of speech or music received may be distorted. In order to secure maximum amplification with a minimum of speech distortion it is usually desirable to use, with amplifier tubes, a "B" battery of rather high voltage. It is usually better to secure this condition by adjustment of the "B" battery than by the use of a "C" battery in the grid circuit. An adjustable voltage for this purpose may be obtained by using a "stabilizer" or potentio meter resistance connected across the terminals of the filament battery. The sliding contact is connected to the part of the circuit which would otherwise connect the grid to the filament or "A" battery. Such a "stabilizer" rheostat is shown at R_1 in Fig. 18. If the input voltage to an amplifier is so great that the output voltage would be more

than the maximum which the tube could carry and still maintain the proportionality, a distortion is bound to result unless tubes of different characteristics are used. In the circuit shown in Fig. 16 a "potentiometer" resistance or "stabilizer" may be connected across the filament or "A" battery in a similar manner to that shown in Fig. 13.

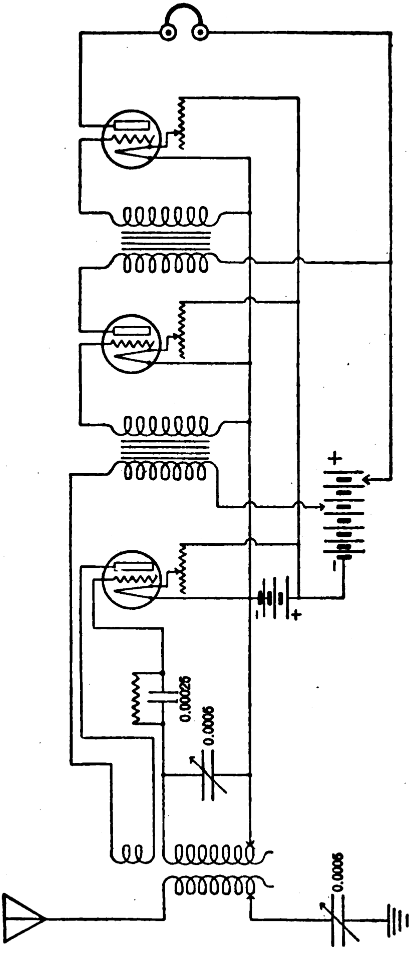

Fig. 16—Diagram of Receiving Set using Electron-Tube Detector and Two-Stage Audio-Frequency Amplifier.

The transformers used in Fig. 16 are called "audio-frequency" transformers, since they are used in the part of the circuit between the detector tube and the telephone receivers. The voltage ratio (*i. e.*, ratio of number of turns of wire in secondary to number in primary) of the audio-frequency transformers usually used is between 5 and 10. The best value of this ratio for any particular set depends both on the design of the amplifier and the characteristics of the tubes used.

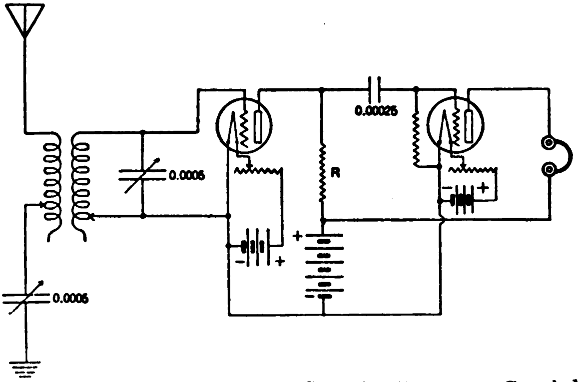

Fig. 17—Diagram of Receiving Set using Resistance-Coupled Radio-Frequency Amplifier.

In order to secure additional amplification without the undesirable howling caused by using an excessive number of audio-frequency amplifier tubes, recourse may be had to the use of a radio-frequency amplifier. The circuit connection for such an amplifier containing only a single tube is shown in Fig. 17. This circuit employs an amplifier tube which is connected between the tuned secondary circuit and the detector tube. Instead of a transformer between the amplifier and detector tubes a large resistance R (approximately 10,000 ohms) is used which is called the "coupling" resistance. This circuit operates well at the longer wave lengths, but is less efficient at the short waves than a properly constructed transformer coupled amplifier as shown in Fig. 18. Other reliable hook-ups are given in the section on "Radio-Frequency Amplifiers" on page 41 of this Chapter.

The circuit used by a six-stage radio-audio-frequency amplifier is shown in Fig. 18. The first three tubes are radio-frequency amplifier tubes; the fourth tube is a detector tube and the last two tubes are audio-frequency amplifier tubes. The same type of tube is used for both radio and audio amplification; the detector tube is of different type. In Fig. 18 the rheostat R_2 controls the current through the radio-frequency

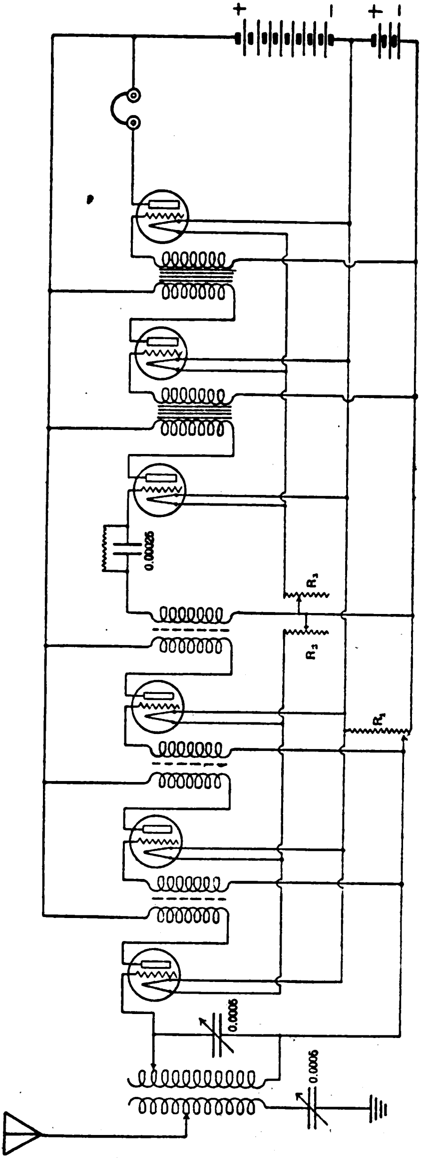

Fig. 18—Diagram of Receiving Set using Radio-Audio-Frequency Amplifier. (Using Amplifier Tubes throughout).

amplifier tubes while the rheostat R_2 controls the current through the detector and audio-frequency amplifier tubes. The transformers connected in the plate circuits of the first three tubes are radio-frequency transformers. These transformers are designed for operation over a particular band of wave lengths, and in order to secure the best results it is important that the three transformers used operate best over the same wave length range.

Radio-frequency transformers may have either an "air core," (*i. e.*, no core at all) or an iron core. The air-core transformers are efficient over a very narrow range of wave lengths but give more amplification per stage. The iron-core type gives a fairly uniform amount of amplification over a much broader range of wave lengths but does not give as much amplification per stage. A radio-frequency transformer for 360 meters can be made by winding about 200 turns of No. 44 B. & S. gauge enameled copper wire in a single layer over a core of thin laminated iron about ½ inch square and 3 or 4 inches long. A layer of some insulating material about 1/16 inch thick should be put around the iron core before the wire is wound on it. This winding can serve as the primary winding, the secondary being an identical one, wound on the same core. The inner ends of the two windings should be separated about ¼ inch from each other. In connecting these transformers to the electron tubes the inside adjacent ends of the windings should be connected to the battery circuits, the extreme outer ends being connected to the grids and plates of the tubes. Varying the number of turns of wire and the distance between these windings changes the frequency or wave length at which the transformer is most effective. The exact values best for a certain wave length can be determined by trial.

Three-Circuit Set.—The connections used in a three-circuit tuner are shown in Fig. 19. Here in addition to

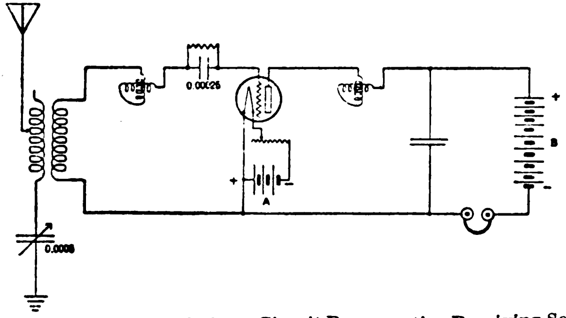

Fig. 19—Diagram of Three-Circuit Regenerative Receiving Set using Electron Tube Detector.

the primary and secondary inductance coils forming the coupler, or variocoupler, it is necessary to use two additional variable inductance coils which are usually of the form known as "variometers." These variometers are quite similar in appearance to the variocoupler, but the two windings are connected in series so that as the position of one of the coils is changed, the inductance is correspondingly varied.

This is a regenerative circuit, in which, however, the feed-back action is accomplished by the capacity between grid and plate instead of by a tickler coil. Both the plate and the grid circuit are tuned by the combination of the tube capacity with the variometer in that circuit. The condenser at the right is merely to give the radio-frequency current an easier path than it would have through the phones and battery. Since the amount of feed-back can not be varied directly, as it can be in regenerative sets employing a tickler coil, this type of set is very difficult to adjust (see page 11). Any change of setting of the coupler coupling or of either variometer varies the adjustment of the others. It rewards patience by giving loud signals, but is troublesome to operate.

It is necessary to provide for fine adjustment of the antenna wave length, either by strictly continuous variations of the inductance in series with the antenna or by the series condenser. If the series condenser is not used, because of receiving longer waves, the condenser may be placed in parallel with the antenna inductance coil and serve as fine adjustment of it.

Loading Coils for Long Waves.—Single-circuit and coupled-circuit receiving sets which are designed for short-wave reception may be modified for use in receiving signals from longer wave stations by the addition of loading coils. In the single-circuit set this loading coil is connected in series in the antenna lead wire. In the coupled circuit set one loading coil is connected in the antenna circuit and another similar one is connected in series with the coil and condenser of the secondary circuit. The two circuits must be tuned to the same wave length. An example of a long wave station to which it is sometimes interesting to tune is the Arlington station of the U. S. Navy Department. This station sends out time signals on a wave length of 2650 meters.

Loading coils for tuning a 360 meter single-circuit or coupled-circuit receiving set to this 2650 meter wave length may be made by winding about 300 turns of wire (Nos. 20 to 24) on a cylinder about 4½ inches in diameter and bringing out taps every 25 turns in order to make connections which will tune to various wave lengths. The loading coils should be entirely removed from the circuit when the set is used to tune to short wave lengths since they greatly decrease the efficiency

of the set by introducing capacities which result in power loss. Even when tuned to receive long-wave signals, a loaded set is not as efficient as one which is originally made according to the proper design for this use. Nevertheless the use of a loading coil to extend the wave length range of a short wave set is thoroughly practicable; the long wave stations which it is desired to hear are usually of higher power than the short wave stations and can therefore be easily heard. It is not practicable to attempt to load a three-circuit tuner to receive signals of longer waves than those for which it is designed.

Accessories.—For use in constructing or assembling receiving sets, there are several accessory parts which are required, but which can be readily purchased from almost any dealer in electrical supplies. These include binding posts, rotary lever switches, battery switches, knobs, dials, wire, buzzer, cardboard tubing, panel parts, etc. The requirements as to numbers and sizes and other particulars are dependent upon the circuit which it is desired to follow.

Series and Parallel Condensers.—The series condenser shown in the antenna circuit of Figs. 10, 12, 13, 14, 16, 17, 18, 19 is not necessary if the antenna is short enough to enable one to tune to the desired wave length by the adjustment of the series inductance coil. The shorter the wave, the lower will be the setting of the series condenser. If the desired wave length is longer than that to which the series inductance makes it possible to tune, the wave length of the antenna circuit may be increased somewhat by connecting the condenser across the terminals of the series inductance. This condenser can conveniently be a variable condenser having a maximum capacity of 0.0005 microfarad. Either the series or the parallel condenser serve the added purpose of enabling one to tune more closely to the wave length desired by making finer adjustment of the tuning of the circuit than may be obtained by varying the number of turns of the coil only.

Construction Details of Receiving Sets.—When a receiving set is assembled in a box it is desirable to use a sheet of metal as a lining of the front panel in order to reduce the effect of the hand of the operator on the capacity between the parts of the set. This shield should be connected to the negative terminal of the filament or "A" battery or else to the ground terminal of the receiving set.

In assembling a receiving set all connecting wires should be as short as possible and should run in as nearly straight lines as is consistent with keeping them spaced well apart from one another. The size of the connecting wires is not especially important though it should not be extremely small. Wire of any size between No. 26 and No. 14 B. & S. gauge is satisfactory

though slight preference should be given to the heavier wire.

In theory it would be desirable in winding coils and in wiring up radio sets to use wire having many fine strands insulated from one another and woven together in the form of a cable. Such a conductor is called "litzendraht," or "litz," or "high frequency cable" and would be expected to have a lower resistance to radio currents than solid wire of the same weight. Since the insulation can not be infinitely thin, however, it turns out that for very short waves solid wire is better than any actual stranded wire. Practically, moreover, it is difficult to insure that the fine strands are continuous and not broken and that they are all completely insulated from one another. It is not easy to make a soldered connection to all of the strands forming such a cable. It is, therefore, usually not worth while to use other than solid copper wire in the construction and assembly of ordinary radio receiving apparatus.

Some of the variometers and variocouplers on the market employ the shaft as a connection to one side of the rotating ball or coil. If this type of variometer is purchased it should be seen that the shaft end which projects through the shielding panel is at the grounded end of the circuit. In the case of the variocoupler it is usually better not to use the shaft as a connection. Direct flexible connections should be made to the coils and the shaft should be grounded to the shield.

Sometimes inductance coils are used which have a very large number of turns, only a few of which are used for tuning to short wave signals. It is best in such a case to have a switch called a "dead-end" switch for entirely disconnecting the major part of the coil when not in use. This decreases the loss of power in the unused portion of the coil.

When a coil of many turns is wound in the ordinary way in several layers the distributed capacity is made larger than if the same wire were wound in a single layer. The objectionable length of a single layer coil is avoided and the advantage of low distributed capacity is partly retained by coils wound with a basket form of winding. In such coils there is a considerable air space between the wires. This method of winding often makes the coils self supporting.

It is desirable to have as little solid dielectric as possible in the region immediately surrounding the wires of an inductance coil. The existence of solid insulation results in the loss of power and the decrease of signal strength. Even the enamel or silk insulation on wire is a cause of loss of power though of course the adjacent turns on a coil must be kept out of metallic contact with one another. Cotton insulation is better on this account and it is also less expensive. No

shellac should be used for the coating or impregnation of coils on account of the power loss which it causes.

On variometers where the scale is not fixed in position on the shaft, the dial should be made to indicate the minimum or zero position when the coils are in such a position that the current flows in opposite directions in the two coils.

Provision should be made for disconnecting both the "A" and the "B" batteries from the set when not in use, in order that they may not needlessly become discharged.

A grid leak resistance may be made by drawing a rather heavy line with a soft pencil on a piece of card board about 1½ inches long and connecting it across the terminals of the grid condenser. The best adjustment of this resistance can be determined by trial by widening it or by narrowing the line by erasure.

How to Remedy Receiving Circuit Troubles.— Receiving sets like other electrical apparatus may suffer from short circuits or open circuits. An open circuit often makes itself known by a low pitched hum in the telephone receivers. A simple way of testing for this trouble is by the use of a telephone receiver and dry cell. On account of the small distance which is allowed between the fixed and moving plates of the variable condensers it is possible for these condensers to become short circuited at certain positions on the scale. The telephone receiver and battery may also be used for locating this trouble. It may be remedied by giving the bent plate a slight push with a screw driver while care is taken to avoid bending the adjacent condenser plates. In some condensers the position of the shaft carrying the movable plates is adjustable and may be changed by means of nuts located on the base of the condenser. Sometimes the telephone receiver cord becomes defective. This is noted by a rasping or scratching sound or a click when the telephone cord is moved. A new telephone cord can be obtained for a small sum from any radio supply store. In a regenerative receiver if the adjustment of the grid and plate variometers or the tickler coil fails to produce regeneration, the filament current and plate voltage should be changed. If the filament of an electron tube fails to light or flickers, the tube should be removed from its socket and the ends of its four contact prongs should be cleaned with sandpaper or a fine file. It should be made certain that the spring connections in the tube socket make good contact with the prongs on the tube. It is desirable to try various combinations of the tubes used as detector and amplifier tubes since it is possible to find a best arrangement of these tubes in the various parts of the circuit. When the filament of an electron tube is burned out there is no remedy other than to replace the tube by a

new one. Repaired tubes are not likely to be satisfactory unless as great care is taken with the repairing as is required in manufacturing. It is especially difficult to be sure that the vacuum will hold.

Noises.—Grinding noises which persist when the antenna and ground wires are disconnected from the receiving set are not caused by atmospherics or "static" but may usually be remedied by tightening the connections to the binding posts at various parts of the circuit, by cleaning the contacts of the tubes, or by replacing old "B" batteries by new ones. Sometimes an electron tube is found which has a poor connection between the filament itself and the lead wire, which connects the filament with the prong on the base. Such a tube should be removed from the circuit and replaced by a new one.

Interference from Radio Stations.—Interference from undesired radio stations or from atmospheric electricity is obtained only when the antenna and ground wires are connected to the receiving set. The interference from spark stations can be recognized by the long and short buzzing sounds constituting the dots and dashes of the radio telegraph code. Such stations may be either commercial radio stations, such as operate between ship and shore or may be amateur spark stations. Such interference can be minimized by reducing or loosening the coupling between the primary and secondary circuits or by reducing the tickler or regenerating action of the receiving set. Interference from continuous wave transmitting stations or from nearby receiving stations which are so adjusted as to act as weak transmitters is recognized by a whistling sound or continuous musical note. If it is found that the pitch of this musical note changes as the receiving set is detuned, this is an indication that the receiving set at hand is also generating and acting as a feeble transmitter. The tickler or regenerating action should therefore be reduced. When the adjustment passes this generating point a click will be heard in the telephone receivers.

Sometimes it is noticed that the strength of the signals received from distant stations varies rapidly for no apparent cause. This is particularly true at night when the signals may fade in and out regularly or irregularly. While it is advisable to make sure that the connections to the receiving antenna are not loose, this difficulty is usually caused by changes in the condition of the space through which the radio waves travel between the transmitting and receiving stations. This difficulty is therefore obviously entirely out of the control of the receiving set manufacturer or user.

Weak Signals.—If the signals which are customarily loud from a station are suddenly found to be quite

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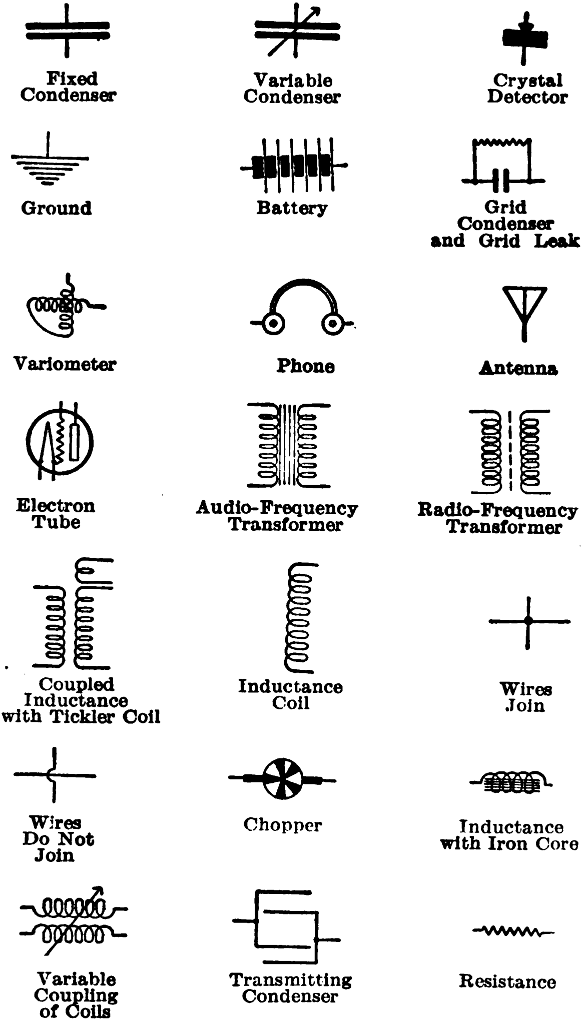

weak, the difficulty may be caused by one or more of the following:

a. The transmitting station may have reduced its power.

b. The crystal detector of the receiving set may be out of adjustment or may have become dirty. In the latter case the metal point which touches the crystal may be filed and the surface of the crystal washed with soap and water. Care should be taken not to touch the surface of the crystal with the fingers.

c. The receiving antenna may have become disconnected or may have fallen from its supports.

d. The ground connection may have become disconnected or the water may have been drawn from the system or water pipes which are used for grounding the set. In the latter case the existence of insulating paint or gaskets may have resulted in making the ground connection ineffective. For further comments on ground connections, see chapter 3.

e. The plate battery may be exhausted.

f. The filament battery may have become discharged.

g. The telephone plug may not be making good contact either by its being pushed too far or else not far enough into the receiving set.

Atmospheric Interference.—Irregular interfering noises heard in the telephone receivers are often caused by atmospheric electricity. These disturbances are variously called "strays," "static," "atmospheric," "atmospheric disturbances," and other names. There are probably many causes for these stray waves, but their sources have never been completely explained. They are more troublesome in the summer time then in the winter and are also more serious in tropical latitudes than in northern regions. The most satisfactory methods of reducing this atmospheric interference are the use of small antennas with very sensitive amplifiers and the use of very loosely coupled circuits. Radio telephony has an advantage over radio telegraphy when it is necessary to receive through this type of interference, since speech can often be understood by context even though some parts of it are lost. Some sources of interference which produce sounds very similar to atmospherics are the leaking of electric currents over the surface of faulty insulators of power lines, the sparking at commutators of electric motors, sparking at the contact of trolley wheels with the trolley wires, the irregular operation of arc lights and the operation of X-ray machines. In some cases a continuous hum is heard on account of the antenna or ground wire being run parallel to an electric light or power circuit. This can be reduced by moving the antenna to a position at right angles to the power line. When it is desired to use a receiving station for continuous reliable reception of any radio service, it is advisable to investigate the possibility of such causes of interference in the immediate neighborhood as have just been mentioned.

Automatic Filament Control.—Fig. 20 shows an arrangement by which the electron tubes are automatically lighted as needed. Insertion of the telephone receiver plug in any jack causes the needed tubes to light up, and the needed tubes only. That is, when the phone plug is inserted in jack 3 all three tubes light up; when in jack 2 only the detector tube and first audio-frequency amplifier tube light up; and when in jack 1 only the detector tube is lighted. Removing the

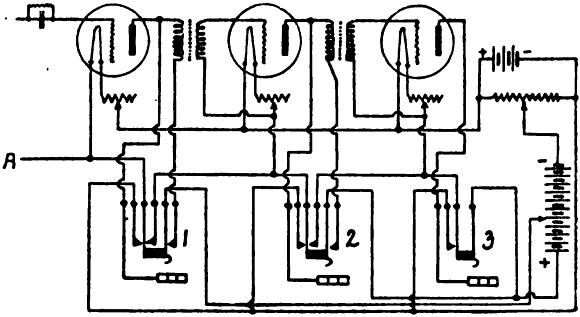

Fig. 20—Connections to Jacks for Automatic Filament Control of Detector and Two Stages of Audio-Frequency Amplification.

phone plug automatically stops the drain on the filament battery. If radio-frequency stages (not shown in figure) are used, they will be lighted up by insertion of the phone plug in any jack, provided the filaments of the radio-frequency tubes are connected to the point A and to the positive end of the filament battery (either direct or through a potentiometer resistance).

Super-Regenerative Radio Reception—While this advance is based upon a simple principle, anyone who attempts to understand or to use it should have some knowledge of electron tubes as detectors, amplifiers, and generators; of regenerative reception and of coil antennas. The reader is particularly advised to be familiar with the explanation of regeneration in Chap. 5, page 9, and the operation of regenerative receiving sets, Chap. 2, pages 12 and 20. Super-regenerative apparatus is not yet on sale; it probably will be after commercial development by the companies which control the patents on regeneration.

This new method obtains results of the same order as those obtained with good radio-frequency amplifiers

(see Chap. 2, page 25, and Chap. 6, page 4), and does it with fewer electron tubes. It is particularly suitable for amplifying loud signals, but has not been very successful for weak signals from distant stations becasue of noises produced within the apparatus. It makes a receiving set so sensitive that signals from distant stations may be received as loud as desired without an outdoor antenna. Information on the small indoor antennas which may be used with a super-regenerative receiving set is given in Chap. 3, pages 7 to 11, and Chap. 6, page 1. The use of a coil antenna has the following advantages: (*a*) on account of its low resistance it is very selective and signals that are not desired are readily tuned out; (*b*) undesired signals can also be eliminated by turning the coil to such a position as not to receive them; (*c*) the coil does not re-radiate the power in a super-regenerative set nearly as much as the elevated wire antenna, and hence does not cause disturbance in other receiving sets in the neighborhood.

The ordinary process of regeneration is one by which a single electron tube is made to do the work of several tubes as amplifiers. This is done by connecting the output (plate circuit) of the tube back to the input (grid circuit) instead of connecting to a second tube. This "feed-back" is accomplished by such devices as the "tickler" coil. If the feed-back is greatly increased, as by increasing the tickler coil coupling, the electron tube becomes a generator (as explained on page 12, Chap. 5), and hissing or sharp rumbling noises are heard in the phone instead of the desired signals. The sensitiveness of the electron tube as an amplifier increases as the feed-back coupling is increased up to this point of self-generation ("oscillation") which spoils the incoming signals. This self-generation has therefore been the limit to which the feed-back process could be carried.

Super-regenerative reception is a method whereby the feed-back or regenerative process can be carried much farther than the limit heretofore imposed by self-generation. It depends on the fact that self-generation does not take place instantaneously but requires time for the generated current to build up to its final value. The feed-back is made sufficiently great so that self-generation would normally take place, but after a brief instant the feed-back is reduced so that the self-generated current dies out. The feed-back is made to alternate repeatedly above and below the value required for self-generation. During the time that it is above this value, the current in the tube builds up rapidly and to a much larger amount than with ordinary regeneration, and during the intervals when it is below this value the current practically dies out. The alternation in the feed-back is made to take place at a rate so rapid as not to interfere with the signal.

Super-regeneration is accomplished by introducing in the ordinary regenerative circuits anything which periodically varies the feed-back above and below the point required for self-generation. The voltage which the tickler coil feeds back into the grid circuit depends upon the direct voltage existing in the plate circuit. Super-regeneration may therefore be brought about by introducing some form of alternating current generator (G, Fig. 21) in series with the B battery.

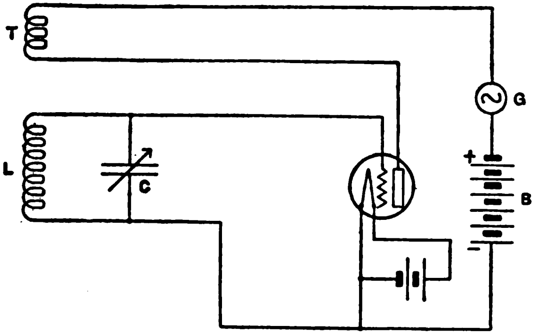

Fig. 21—Periodic variation of feed-back voltage.

When the voltage in this generator is in the same direction as the voltage from the battery, the feed-back increases beyond the point of self-generation and the current builds up to a very large value; when the voltage reverses the current dies out.

The same thing can be accomplished in another way. The value of the feed-back is affected by the resistance in the tuned circuit (C L) connected to the grid. If the tickler coil is adjusted so as to be almost on the point

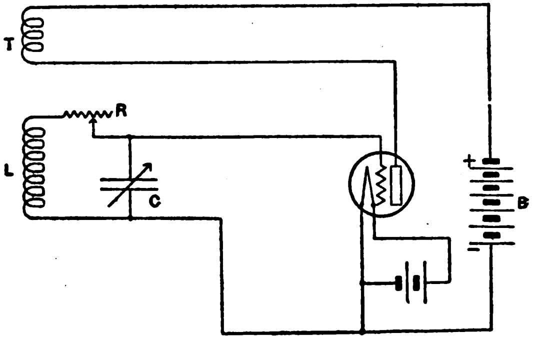

Fig. 22—Periodic variation of resistance of tuned circuit.

for self-generation, a reduction of the resistance of the tuned circuit will start the current building up to a very large value. If the resistance is then increased again the current will die out. Super-regeneration is thus accomplished by introducing in the tuned circuit (C L, Fig. 22) a resistance (R) which is made to vary periodically.

The actual means that have been used to produce super-regeneration, either the generator in the plate circuit or the variable resistance in the grid circuit, consist of auxiliary electron tubes. For example, instead of using a rheostat with a contact sliding back and forth for the variable resistance R in Fig. 22, the grid and filament of the tube are shunted by a connection to the grid and filament of another tube (G, Fig. 23) which is generating current at some frequency

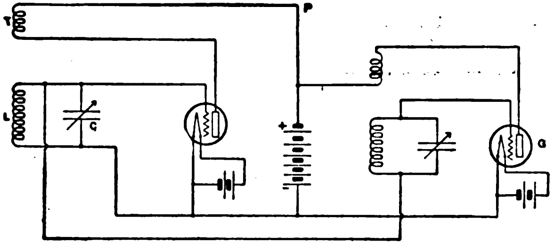

Fig. 23—Resistance variation by parallel connection of auxiliary generating tube.

lower than the received radio frequency. During one-half of the cycle of current generated by the auxiliary tube G, it draws current from the tuned circuit C L, thus having the same effect as increasing the resistance of C L. The resistance thus rises and falls periodically at the frequency of the current generated by the auxiliary tube G.

Signals may be received by inserting a phone at the point P in the plate circuit and something less than 5 volts negative on the grid. Still louder signals may be received by connecting an ordinary amplifier tube to the system. The way this is done is shown in Fig. 24, which gives Armstrong's figures on the details of the circuit. Tube 1 is the super-regenerative amplifier tube, tube 2 is the generator, and tube 3 is the audio-frequency amplifier. The generator tube (tube 2) employs capacitive coupling instead of inductive coupling as in Fig. 23, and the plate voltage is supplied to this tube through a filter to keep out the generated current. The amplifier tube (tube 3) is connected through any good audio-frequency transformer in the ordinary way. All three tubes are Western Electric L tubes (V. T.—2). Other amplifier tubes, such as the U. V. 201, or small power tubes, may be used, with plate voltages as high

as the tubes will stand. Power tubes are preferable. All tubes must be of the same type but need not be matched. The various coils, condensers, batteries, and other parts are the standard types used in radio apparatus. The condensers marked 0.0025 and 0.005 are set once for all for a frequency of about 15,000 cycles per second.

Operation is as follows: Signals are tuned in by varying the 0.001 condenser in the Tube 1 circuits. The 0.001 condenser in the Tube 2 circuit is then adjusted for loudest signal. The 0.001 condenser in the Tube 1 circuits is then adjusted once more for loudest signal. Both directions of the connection to the filament battery should be tried, as the signals will be much better with one connection than the opposite. The operator should not be discouraged if results are not obtained immediately. It should be remembered that it took Armstrong six months to get the results.

The super-regenerative method may be used in a great variety of forms. The functions of super-regenerative amplification, generation, and detection may each be performed in separate tubes; they may be combined in various ways, or all functions may even be combined in a single tube. When the whole thing is done in a single tube it is very complicated to operate.

The three-tube arrangement is by far the easiest one to tune and for this reason only the circuit diagram of the three-tube set is given. In the other arrangements the various tuning adjustments affect one another.

This method may be used to receive any kind of radio signals, telephonic or telegraphic. It constitutes a new and independent method for receiving "continuous-wave" signals. When receiving such signals, the frequency generated in the set for periodically varying the feed-back, called the "variation frequency" is a low audible frequency. In Fig. 24, which is for radiophone reception, the variation frequency is 15,000, so as to be inaudible and not disturb the sounds received. It is best to keep the variation frequency as low as possible, because the lower this frequency the more time there is for the incoming current to build up. The sensitiveness of the method is proportional to the ratio of the wave frequency to the variation frequency. For this reason it is very well adapted to short waves, and will probably be valuable in extending the use of waves much shorter than any now in use.

Notes

Variocoupler must have at least 50 turns on secondary.

Either duolateral or honey-comb coils may be used for the 1250 and 1500 turn inductance. These coils should be kept apart and be mounted at right angles.

"B" battery of less than 200 volts may be used but results will not be as good.

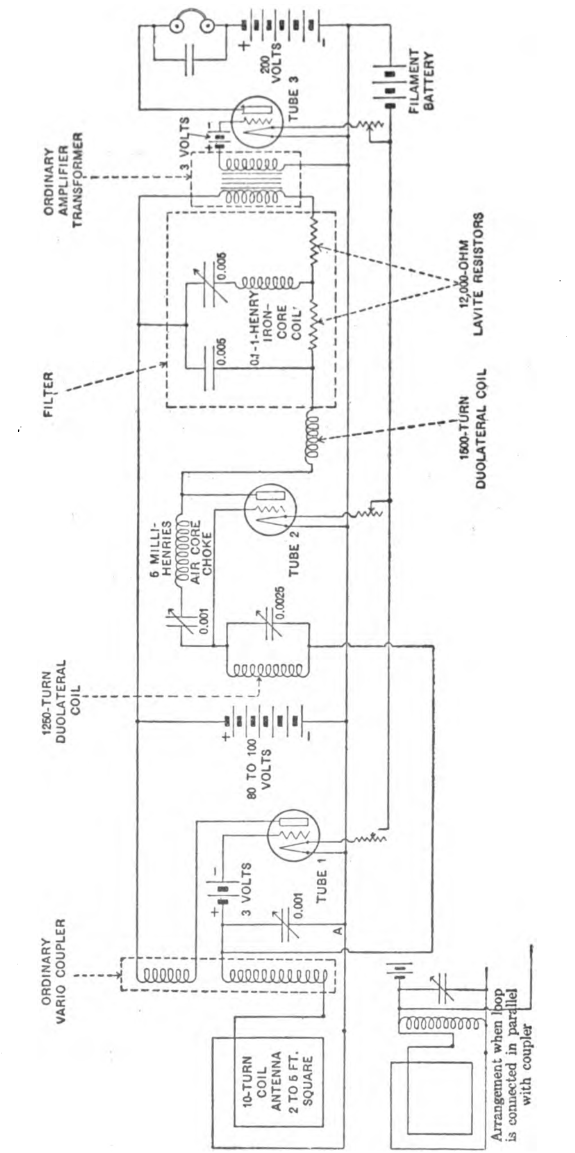

Fig. 24—Super-regenerative circuits for radiophone receiving at 360 or 400 meters.

The 80-100 volt battery need not be variable.

While a 200-volt battery is shown at the right of Fig. 24, this can utilize in part the "80 to 100 volt" battery to the left, so that only a 100-volt additional battery need be provided; this is done by breaking the connection shown at negative end of right-hand battery and running instead a connection from negative end of right-hand battery to positive end of "80 to 100-volt battery."

The 12,000 ohm resistors are non-inductive, this however, is not necessary, Grid leaks of proper value will function equally well. These resistors need not be variable and a tolerance of several thousand ohms is permissible.

The 5-millihenry air-core choke can be either closely wound or spread out but is preferably of the former type.

The same number of turns are used for a 2-ft. loop as for a 5-ft loop. Because of the variable value of inductance in standard variocouplers it is necessary to try connecting the loop both in series and in parallel with the primary of coupler as shown in Fig. 24. Adopt the connection which enables you to tune within the range of the variable condenser 0.001. If this is impossible with either connection, then reduce the number of turns on coil antenna until the desired result is obtained.

It is immaterial whether the grid tap "A" be as shown or tapered into filament rheostat.

Generally speaking, run plate voltage as high as tubes will allow.

No special points need be observed in wiring this set beyond those given on page 29 of Chap. 2.

Radio-Frequency Amplifiers—The following information supplements that given previously in this chapter in connection with Figs. 17 and 18, and in Chap. 6, page 4. Particular attention is invited to Figs. 28 and 29, which show how to combine radio-frequency amplification and regeneration. This is a development of great importance, because the ordinary regenerative set does not have radio-frequency amplification between the antenna and the regenerative tube and consequently acts as a transmitting station when in the generating condition and gives rise to the objectionable interference that has become so common.

One of the best ways to secure loud signals from nearby radio stations or satisfactory reception from distant stations is by employing radio-frequency amplification. By this method the radio-frequency current of a receiving antenna is amplified before it reaches the detector. It is then converted into current of a lower or audible frequency, which is made, either directly or through an audio-frequency amplifier, to operate the telephone receivers or loud-speaking reproducer.

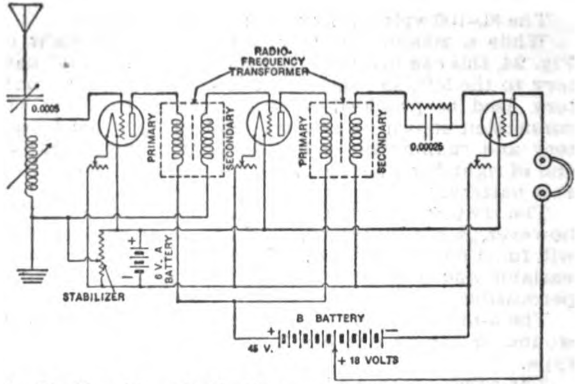

Fig. 25—Two-Stage Radio-Frequency Amplifiers and Electron Tube Detector.

Radio-frequency amplification and regeneration can be combined in the same circuit, thus obtaining the sharpness of tuning which is characteristic of the latter. Two circuits by which this is accomplished are shown in Figs. 28 and 29.

The radio-frequency amplifier ordinarily consists of several electron tubes connected successively through radio-frequency transformers. The circuit given in Fig. 18, page 26 of Chapter 2, shows the connections of a receiving set which employs both radio-frequency and audio-frequency amplification. The first three transformers shown in that circuit are radio-frequency transformers and should be such as to give greatest amplification at the wave length of the signals from the desired station; for example, 360 meters (833 kilocycles per second). These transformers may either be purchased or may, with some experimenting, be constructed by the user. A description of the construction of an iron-core radio-frequency transformer is given on page 27 of Chapter 2. Air-core transformers, when properly made

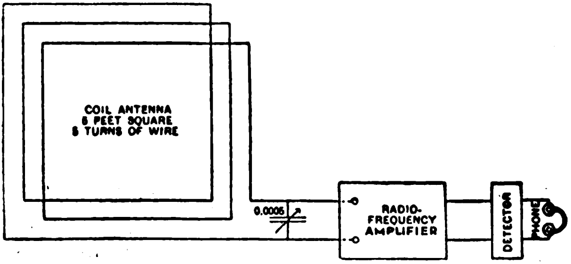

Fig. 26—Essential Connections of Radio-Frequency Amplifier Set Using Coil Antenna.

and used, give greater amplification but are limited in their usefulness to a narrower band of wave lengths.

The two windings or coils of an air-core radio-frequency transformer are usually identical in construction. A suitable design is as follows: Wind about 300 turns of No. 38 B & S. gauge single silk covered copper wire in a form having an inside diameter of 1¼ inches, and a thickness of 3-32 inch. If this coil is wound in the so-called "basket" or "honeycomb" style, the distributed capacity of the coil will be kept low. This is an advantage.

The two similar coils forming the two windings of the transformer should be mounted coaxial and parallel to each other and about half an inch apart. The wave length to which the transformer is tuned can be increased somewhat by moving the coils closer together. The wave length may be decreased by separating the coils slightly or by removing some of the turns of wire.

The stabilizer rheostat, R_3, of Fig. 18 (page 26 of Chapter 2) makes possible the adjustment of the voltage of the grids of the radio-frquency amplifier tubes to give a minimum of distortion. Care must be taken to keep this adjustment below the point where the circuit "oscillates" or becomes a generator of radio-frequency current. In the latter case a hissing or a whistling sound is usually heard which seriously interferes with the received signals.

A somewhat simpler circuit is that shown in Fig. 25, which includes two radio-frequency amplifier tubes and a detector tube. In place of the telephone receivers connection may be made to an audio-frequency amplifier. In this figure the antenna is shown connected to a single-circuit tuner. The connection to a coil antenna is shown in Fig. 26. The amplifier may be any one of those shown in Figs. 17 or 18 of Chapter 2 (pages 25 and 26) or Fig. 25.

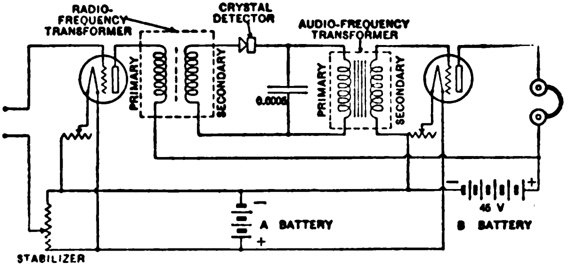

Fig. 27—Amplifier Consisting of One Stage of Radio-Frequency Amplification, a Crystal Detector, and One Stage of Audio-Frequency Amplification.

It is possible to use a crystal detector in place of the electron tube detector in a multi-stage amplifier. In this case the circuit shown in Fig. 27 may be used.

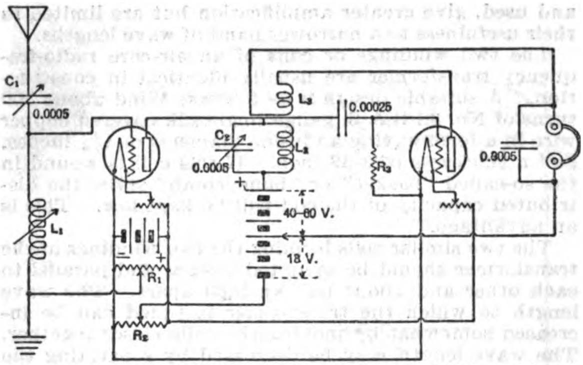

Fig. 28—One-Stage Radio-Frequency with Tickler Coil for Regeneration.

While this diagram shows only one stage of radio-frequency amplification and one stage of audio-frequency amplification, it is possible to use either two or three stages of either, employing connections similar to those in the other diagrams referred to above.

The ordinary radio-frequency amplifier circuit is not capable of such sharp tuning and is not so selective as a well-designed regenerative receiving circuit. This is particularly true when a direct connection is made to the tuning inductance in the antenna circuit as shown in Fig. 25, rather than by the use of coupled circuits as in Fig. 18, page 26 of Chap. 2. The circuit shown in Fig. 28 employs two tuned circuits and, in addition, has a feed-back or tickler coil which is used both to increase the strength of the received signals and to sharpen the tuning of the second resonant or tuned circuit. The first tube is used as a radio-frequency amplifier and the second tube is a detector. The detector circuit is almost identical with the single-circuit regenerative receiving set shown in Fig. 14, page 21 of Chap. 2. In fact, any single circuit regenerative receiving set may be connected to the plate circuit of a radio-frequency amplifier tube, and used in this way.

Fig. 29 differs from Fig. 28 by the substitution of a variometer for the tickler coil in the plate circuit of the detector tube and by the addition of one more stage of radio-frequency amplification (including a radio-frequency amplifier transformer) and one stage of audio-frequency amplification.

If a single circuit tuner is used as L_2C_2 in either Figs. 28 or 29, it is necessary to make sure that the coil and condenser are in parallel with one another. A tuner having the coil and condenser connected in series can be used by connecting the antenna and ground terminals together for one terminal and bringing out a special con-

and used, give greater amplification but are limited in their usefulness to a narrower band of wave lengths.

The two windings or coils of an air-core radio-frequency transformer are usually identical in construction. A suitable design is as follows: Wind about 300 turns of No. 38 B & S. gauge single silk covered copper wire in a form having an inside diameter of 1¼ inches, and a thickness of 3-32 inch. If this coil is wound in the so-called "basket" or "honeycomb" style, the distributed capacity of the coil will be kept low. This is an advantage.

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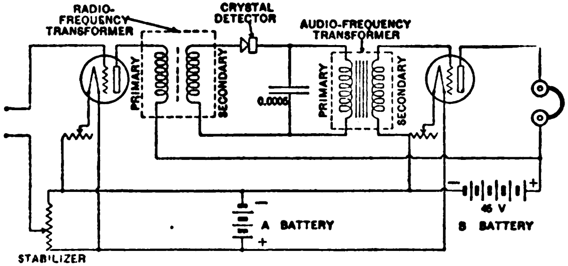

Fig. 27—Amplifier Consisting of One Stage of Radio-Frequency Amplification, a Crystal Detector, and One Stage of Audio-Frequency Amplification.

It is possible to use a crystal detector in place of the electron tube detector in a multi-stage amplifier. In this case the circuit shown in Fig. 27 may be used.

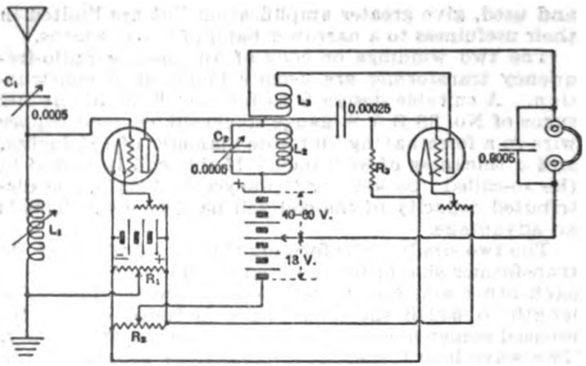

Fig. 28—One-Stage Radio-Frequency with Tickler Coil for Regeneration.

While this diagram shows only one stage of radio-frequency amplification and one stage of audio-frequency amplification, it is possible to use either two or three stages of either, employing connections similar to those in the other diagrams referred to above.

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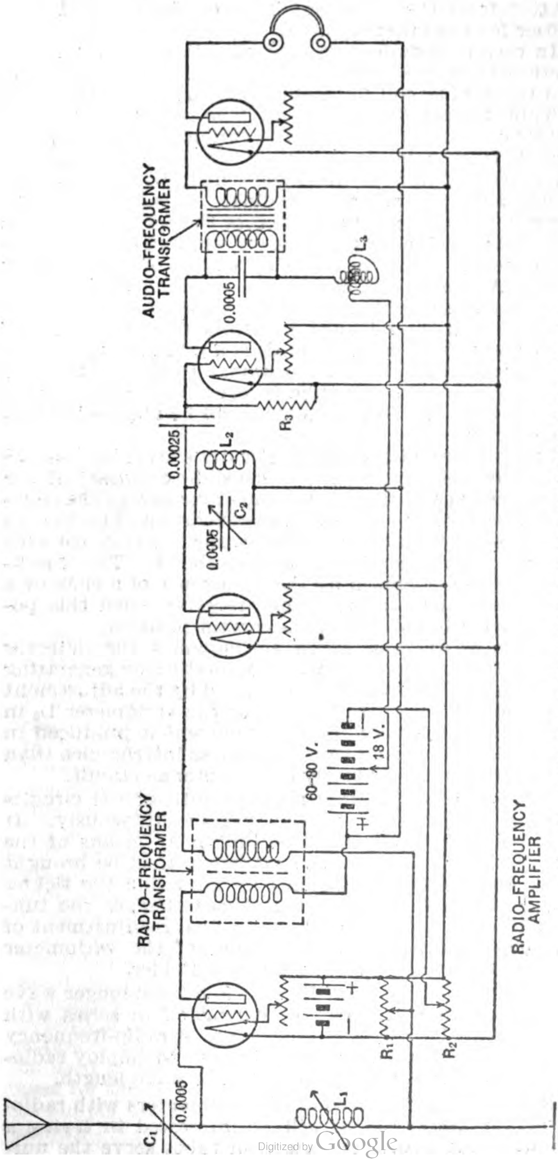


Fig. 29—Two-Stage Radio-Frequency and One-Stage Audio-Frequency with Variometer for Regeneration

nection from the mid-point between the coil and condenser for the other terminal.

In case it is desired to construct the coils for use in these circuits, the tuning coils L_1 and L_2 should be made like the tuning coil for a single circuit tuner described in Table 2, page 14 of Chap. 2. The construction of the tickler coil, L_3, Fig. 28, and the variometer for the plate circuit, L_3, Fig. 29, is also described in the same table. As much air and as little solid dielectric as possible should surround the coil winding. It is important to use a condenser, as shown, across the terminals of the telephone receiver or the primary winding of the audio-frequency amplifier in the plate circuit of the detector tube. A condenser across the terminals of the A battery also slightly increases the signal strength. The resistances R_1 and R_2 are A battery potentiometers of 200 or 300 ohms each, while R_3 is a grid leak resistance of approximately half a megohm. In case a hard or high-vacuum detector tube is used, a slightly higher voltage than the 18 volts shown will be required for its plate circuit.

In operating either of the circuits shown in Figs. 28 and 29 one should not move the sliding contact of the stabilizer or potentiometer, R_1, near enough to the negative A battery end to cause the generation of current in the antenna circuit. To do so causes interference with other receiving sets in the neighborhood. This condition can be recognized by the occurrence of a click or a hissing sound in the telephone receiver when this potentiometer is moved past a certain position.

The sensitiveness which accompanies the detector tube when it is nearly in this oscillating or generating condition, can, however, be obtained by the adjustment of the feed-back L_3, in Fig. 28, or the variometer L_3 in Fig. 29. The locally generated current is produced in the Circuit L_2 C_2 and thus causes less interference than if it were produced directly in the antenna circuit.

In tuning to a desired station, both of the circuits L_1 C_1 and L_2 C_2 must be adjusted simultaneously. It is convenient to do the final tuning by means of the variable condensers. The signals can then be brought up to the maximum strength by adjusting the tickler coil or variometer. This sometimes changes the tuning of circuit L_2 C_2 slightly and a final readjustment of this circuit is advisable. The use of the variometer causes less change in tuning than the tickler.

To tune the circuits of Figs. 28 and 29 to longer wave lengths loading coils can be connected in series with L_1 and L_2. If more than one stage of radio-frequency amplification is used one must be sure to employ radio-frequency transformers of the proper wave length.

Reflex Amplifier Circuit.—Experimenters with radio-frequency amplification will be interested in trying a circuit which makes two electron tubes serve the pur-

poses ordinarily requiring three tubes. To accomplish this the first tube of the amplifier circuit is used both as a radio-frequency amplifier and as an audio-frequency amplifier. A circuit which can be used to accomplish this is shown in the diagram below (Fig. 30). It will be seen that the radio-frequency current in the receiving antenna is amplified by the first electron tube. The second tube serves as a detector, but in place of the telephone receivers or a connection to additional audio-frequency amplifier tubes, a return connection is made to the input terminals of the first radio-frequency amplifier tube.

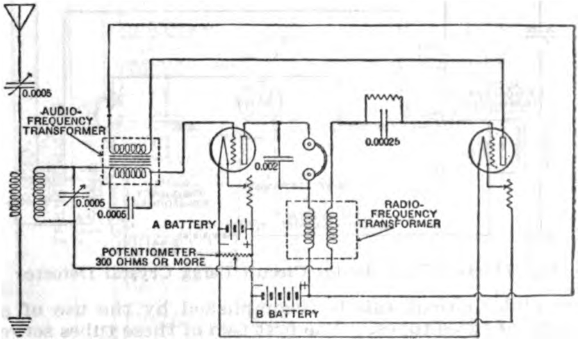


Fig. 30—Two-Tube Reflex Circuit.

The audio-frequency current from the detector tube is thus amplified by the first tube which is simultaneously amplifying the original radio-frequency current. In the plate circuit of the first tube is a connection to the telephone receivers. The telephones do not respond to the radio-frequency current originally passing through the tube, but are affected only by the audio-frequency current which has been brought back to this tube from the detector.

The factors to consider in operating this type of circuit are the necessity of simple wiring and orderly arrangement of the circuit elements. The position of the sliding contact on the stabilizer rheostat is likely also to be important.

In Fig. 30 both tubes are of the amplifier type and the B battery is of 45 volts or more. The tuning equipment is an ordinary variocoupler, specifications for which can be found on page 15 of Chap. 2. A 200-ohm potentiometer will be satisfactory if one of higher resistance cannot be procured. Dry battery tubes can be used in this circuit if desired. A soft tube may be used for the detector if a tap is taken from the B battery to supply its plate with 22½ volts instead of 45 as shown.

A reflex amplifier can be made from a single electron tube and a crystal detector; the single tube serves both as a radio-frequency and as an audio-frequency amplifier. The crystal detector serves the same function as the tube detector shown in Fig. 30. The circuit employing a crystal detector and a single amplifier tube is given in Fig. 31.

If it is desired to have sufficient amplification to operate a loud speaker it is usually necessary to have two stages of audio-frequency amplification. With a reflex

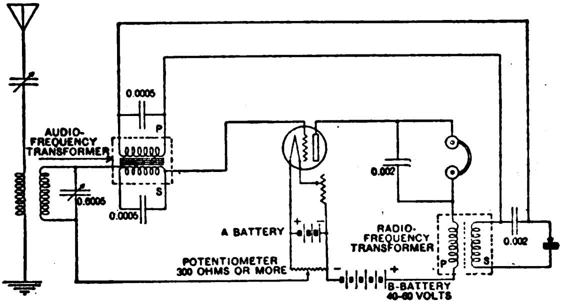


Fig. 31—One-Tube Reflex Circuit Using Crystal Detector

amplifier circuit this is accomplished by the use of a total of three tubes. The first two of these tubes serve as radio-frequency amplifiers and also as audio-frequency amplifiers. The third tube is the detector tube, A reflex circuit using three tubes in this way is shown in Fig. 32. If amplifier tubes are used in all three stages, the B battery voltage should be between forty and sixty-volts. If a soft tube is used as a detector tube, the connection to its plate circuit should be made from the twenty-two volt tap on the B battery. The antenna and secondary inductance coils are the primary and secondary respectively of a variocoupler; or in place of a coupled circuit it is entirely feasible to use a single-circuit tuner. The details of the sizes of coils used in either case are given in Table 2, of this chapter.

If the circuit tends to howl or "oscillate" this can sometimes be stopped by the insertion of a resistance, such as that of a potentiometer, 300 to 2000 ohms, in the plate circuits of the two amplifier tubes as shown at R and R in Fig. 32.

Wave Trap in an Antenna Circuit.—Sometimes if severe interference is suffered from a single transmitting station nearby which uses a wave length slightly different from the wave length of a station which it is desired to hear, the signals from this interfering station may be made much weaker by connecting a wave-trap or filter in the antenna circuit. The connection of a very simple filter for this purpose is shown in Fig. 33. The

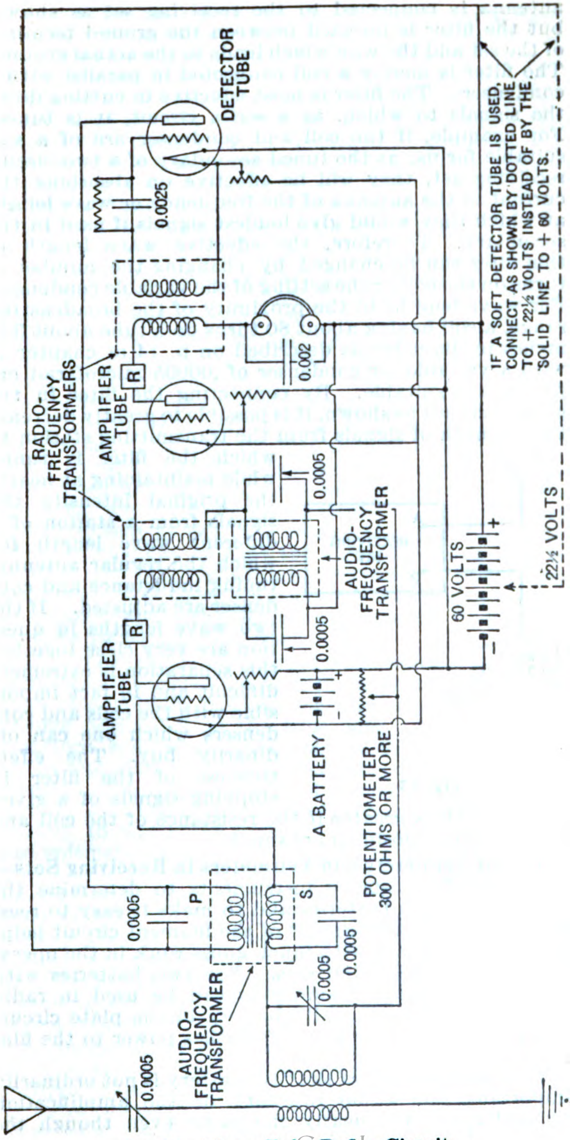


Fig. 32—Three-Tube Reflex Circuit.

antenna is connected to the receiving set as shown, but the filter is inserted between the ground terminal of the set and the wire which leads to the actual ground. The filter is merely a coil connected in parallel with a condenser. The filter is most effective in cutting down the signals to which, as a series circuit, it is tuned. For example, if the coil and condenser are of a size suitable for use as the tuned secondary of a two-circuit receiving set, they will be effective on absorbing the current in the antenna of the frequency or wave length at which they would give loudest signals if used in the secondary. Therefore, the effective wave length of this filter can be changed by changing the number of turns on the coil or the setting of the variable condenser. For wave lengths in the proximity of the broadcasting range, a coil having about 80 turns on a tube about 3½ inches in diameter as described on p. 14 of chapter 2, with a variable air condenser of .00005 microfarad capacity are suitable. By connecting the filter in the ground circuit as shown, it is possible to greatly decrease the strength of signals from the transmitting station to which the filter is tuned while maintaining at nearly the original intensity the signals from a station of a different wave length for which the regular antenna, tuning inductance and condenser are adjusted. If the two wave lengths in question are very close together this separation is extremely difficult and in fact impossible with the coils and condensers which one can ordinarily buy. The effectiveness of the filter in stopping signals of a given wave length is greater if the resistance of the coil and condenser composing it are small.

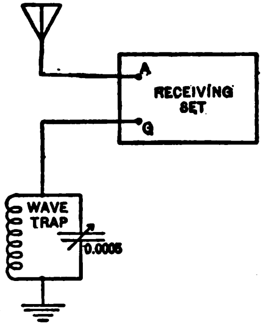


Fig. 33

Use of Ammeters and Voltmeters in Receiving Sets—The use of measuring instruments to determine the condition of the batteries and to make it easy to reestablish a given adjustment of the filament circuit helps greatly to do away with much guess work in the operation of radio receiving sets. The two batteries with which voltmeters or ammeters can be used in radio receiving sets are the "B" battery in the plate circuit and the "A" battery which furnishes power to the filament.

The exact voltage of the "B" battery is not ordinarily important, the signal intensity or the amplification secured remaining nearly the same even though the battery decreases slightly in its voltage during the

course of its use. However, when the battery is nearly discharged the voltage drops rather rapidly and the signals then decrease noticeably in intensity. To determine whether the difficulty in the reception of signals is caused by a worn out or discharged "B" battery, it is convenient to have a voltmeter with which the voltage of the "B" battery can be measured. Since the voltages used in ordinary receiving sets are of the order of 20 volts for the detector tube and 40 to 80 volts for the amplifier tube, a direct current voltmeter having a maximum reading of about 100 volts is useful.

In the filament circuit either a voltmeter or an ammeter may be used. An ammeter connected in series with the filament of a tube reads the current flowing through it and through the filament from the "A" battery. When the filament rheostat has been adjusted so that the signals are received most satisfactorily, the reading of the ammeter is noted. Then, at a subsequent time when the receiving set is being used, the filament rheostat can be brought to the position corresponding to this same ammeter reading and the operator can be quite certain that this adjustment is correct and thus give attention to the careful manipulation of tuning, coupling, and regenerative controls. It will be found, however, that as the tube is used the condition of the filament changes, so that the current flowing through it when the best signals are received will become less and less. It is therefore necessary to make a redetermination of the best value of this current. This should be done perhaps once a week.

If a voltmeter is used to read the voltage across the terminals of the electron tube filament, it will be found that this voltage reading for best signals does not change noticeably as the tube ages. A voltmeter is therefore somewhat preferable to an ammeter as an aid in reproducing the proper conditions in the filament circuit. The voltmeter should be connected across the terminals of the filament itself rather than across the battery to which the filament is connected. That is, the voltmeter readings should not include the voltage across the filament and the filament rheostat, but should read the filament voltage alone. The maximum scale reading of the voltmeter should, however, be slightly greater than the normal voltage of the "A" battery when it is fully charged. This voltmeter will, then, be useful in determining whether this battery is becoming discharged as will appear from a definite decrease in the voltage across its terminals.

In using direct current voltmeters care should be taken to connect the plus terminal of the meter to the positive (plus) terminal of the battery. In many batteries the positive terminal is marked with red. In order to avoid the necessity of having separate voltmeters for each of the tubes used in a receiving set, one

may provide jack and plug connections with which the voltmeter can be plugged into each of the filament circuits in turn. The jack used for a voltmeter connection must be an open circuit jack. That is the circuit must not be closed when the plug is removed. The jack used for making connection to an ammeter should, on the contrary, be a closed circuit jack. That is, the circuit should close when the plug is removed, the insertion of the plug making a connection of the ammeter in series in the circuit.

Converting a Crystal Set Into a Long Distance Set.— The distance range of a crystal detector receiving set can of course be increased by connecting an amplifier between the crystal and the phones. A simpler, cheaper and better way, however, is to convert the set into a regenerative set, using a dry-cell electron tube. With the WD-11 tube an ordinary No. 6 dry cell, the kind used for doorbells, is used instead of a storage battery. By adding such a tube to a crystal set and changing to a regenerative connection, stations at distances up to one or two hundred miles can be heard, under good conditions. Exceptional transmission conditions make it possible to receive over distances up to about 1000 miles.

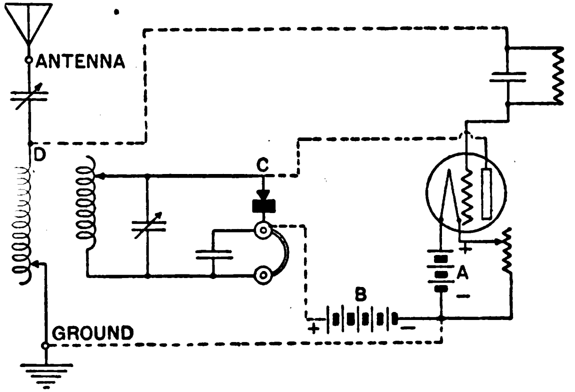


Fig. 34—Regenerative Connection of Electron Tube to a Two-Circuit Crystal Set.

No changes are necessary in the internal connections of the set when you start with a two-circuit crystal set. The ordinary connections of a two-circuit crystal set are shown at the left of Fig. 34. An electron tube with the associated batteries, etc., is shown at the right. The dotted lines between the two show how the connections are made to make the set regenerative. The crystal detector must be out of circuit by having its contact wire raised. If the set does not have a binding-post at points C or D, connection must be made to the proper

switch arm or in some other manner. If the set does not regenerate, the connections to "D" and "Ground" should be reversed.

The parts required for the electron tube detector and their cost, are: WD-11 tube, \$6.50; Tube socket, \$.75; No. 6 dry cell, \$.40; B battery, \$2.00; Filament rheostat, \$1.50; Grid leak and grid condenser, \$1.00.

When you start with a single-circuit crystal set one additional item must be provided, a tickler coil. This

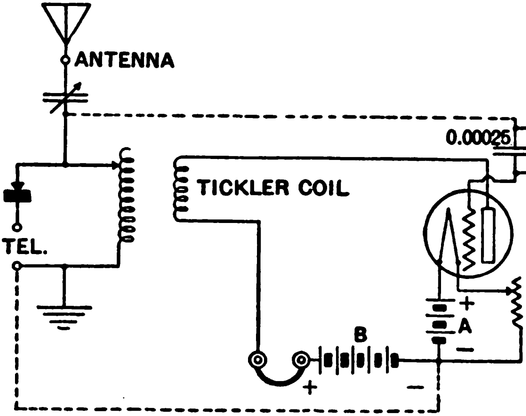


Fig. 35—Regenerative Connection of Electron Tube to a Single Circuit Crystal Set.

may be a simple cardboard tube about 2 inches long and 3 inches in diameter, with about 30 turns of No. 24 to 30 wire wound on it. This must be provided with a means of sliding either inside or over the inductance coil of the set, or else made to rotate within or near it. The ordinary connections of a single-circuit crystal set are shown

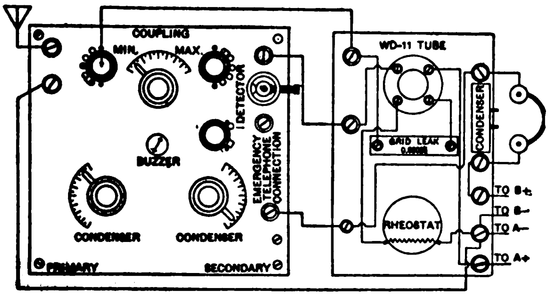


Fig. 36—Connection of Electron Tube Detector to Signal Corps Crystal Set.

at the left of Fig. 35. The dotted lines show how to make the connections to the electron tube and tickler coil.

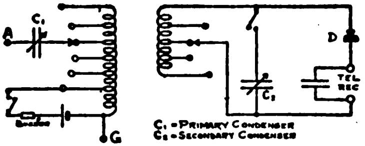


Fig. 37—Internal Wiring of Signal Corps Crystal Set.

Power Amplifier for Loud Speaker.—A number of the loud speakers or loud speaking reproducers on the market at the present time, especially those which are designed to produce a large volume of sound, require a power amplifier for their satisfactory operation. That is, the output of an amplifier using ordinary receiving amplifier tubes is smaller than that required for the production of a large volume of sound from the loud speaker. When ordinary amplifier tubes are used, furthermore, there is distortion of speech and music because the amplifier tubes do not amplify perfectly when used near their limit of power.

An ordinary two- or three-step audio-frequency amplifier can be converted into a power amplifier by replacing the receiving amplifier tubes by transmitting tubes. Five-watt tubes are sufficient for ordinary cases. A higher direct voltage or "B" battery is required in the plate circuit of the power tubes. This depends upon the type of tube used and may be from 100 to 300 volts. If only moderate power is required, the last stage of the amplifier need be the only one having a power tube. It, then, would be the only one for which a higher plate voltage is required.

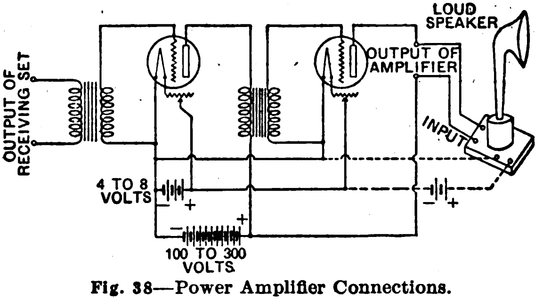


Fig. 38—Power Amplifier Connections.

The circuit shown in Fig. 38 is similar to Fig. 16 of this chapter, but shows how to connect an audio-frequency amplifier to a receiving set which is already in use having a single electron tube detector. The input

The same thing can be accomplished by varying the resistance in the tuned circuit (C L) connected to the grid. If the tickler coil is adjusted so as to be almost on the point for self-generation, a reduction of the resistance of the tuned circuit will start the current building up to a very large value. If the resistance is then increased again, the current will die out.

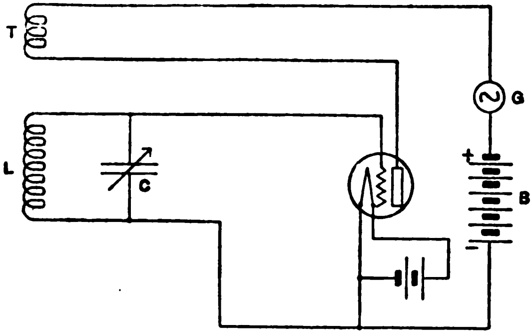


Fig. 36—Periodic Variation of Feed-Back Voltage.

The actual means that are used to produce super-regeneration consist of auxiliary electron tubes. For example, instead of using a rheostat with a contact sliding back and forth to produce a variable resistance, the grid and filament of the tube are shunted by a connection to the grid and filament of another tube (G, Fig. 23) which is generating current at some frequency

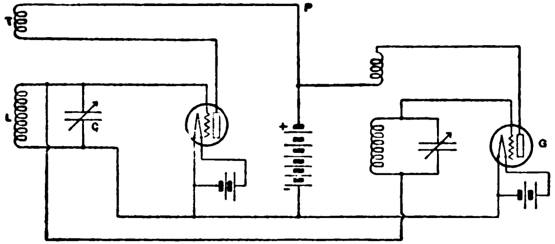


Fig. 37—Resistance Variation by Parallel Connection of Auxiliary Generating Tube.

lower than the received radio frequency. During one-half of the cycle of current generated by the auxiliary tube G it draws current from the tuned circuit C L, thus having the same effect as increasing the resistance of C L. The resistance thus rises and fa'ls periodically at the frequency of the current generated by the auxiliary tube G.

Signals may be received by inserting a phone at the point P in the plate circuit and something less than 5 volts negative on the grid. Still louder signals may be received by connecting an ordinary amplifier tube to the system. The way this is done is shown in Fig. 38. Tube 1 is the super-regenerative amplifier tube, tube 2 is the generator, and tube 3 is the audio-frequency amplifier. The generator tube (tube 2) employs capacitive coupling instead of inductive coupling as in Fig. 37, and the plate voltage is supplied to this tube through a filter to keep out the generated current. The amplifier tube (tube 3) is connected through any good audio-frequency transformer in the ordinary way. All three tubes may be Western Electric L tubes (VT 2). Other amplifier tubes, such as the UV 201-A, or small power tubes, may be used, with plate voltages as high as the tubes will stand. Power tubes are preferable. All tubes must be of the same type, but need not be matched. The various coils, condensers, batteries, and other parts are the standard types used in radio apparatus. The condensers marked 0.0025 and 0.005 are set once for all for a frequency of about 15,000 cycles per second.

Operation is as follows: Signals are tuned in by varying the 0.001 condenser in the tube 1 circuit. The 0.001 condenser in the tube 2 circuit is then adjusted for loudest signal. The 0.001 condenser in the tube 1 circuit is then adjusted once more for loudest signal. Both directions of the connection to the filament battery should be tried, as the signals will be much better with one connection than the opposite. The operator should not be discouraged if results are not obtained immediately.

The super-regenerative method may be used in a great variety of forms. The functions of super-regenerative amplification, generation, and detection may each be performed in separate tubes; they may be combined in various ways, or all functions may even be combined in a single tube. The three-tube arrangement is by far the easiest one to tune. In the other arrangements, the various tuning adjustments affect one another.

The frequency generated in the set for periodically varying the feed-back, called the "variation frequency," is 15,000, so as to be inaudible and not disturb the sounds received. It is best to keep the variation frequency as low as possible, because the lower this frequency the more time there is for the incoming current to build up. The sensitiveness of the method is proportional to the ratio of the wave frequency to the variation frequency. For this reason it is very well adapted to short waves.

It is highly desirable to use this circuit only on a coil antenna or loop. It generates and radiates sufficient

To reduce or balance this capacity feedback through the tube, Professor Hazeltine connects a small condenser from the grid of one tube to one terminal of the secondary winding of the next tuned radio-frequency transformer. The circuit used in a regenerative neutrodyne receiver is shown in Fig. 40. Fig. 41 shows a non-regenerative neutrodyne receiver with one stage of audio-frequency amplification. Fig. 42 shows a neutrodyne receiver in which a reflex connection is employed to utilize two of the tubes both as radio-frequency and as audio-frequency amplifiers. Each stage of a neutrodyne receiver should be thoroughly shielded from the

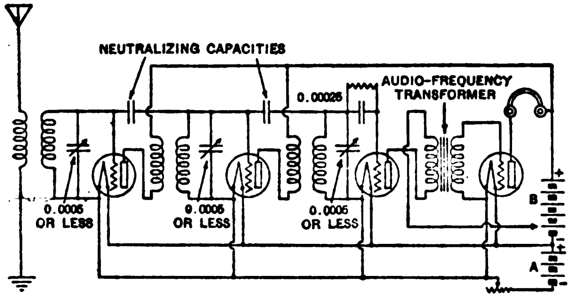


Fig. 41—Diagram of Non-Regenerative Neutrodyne.

next adjacent stages by means of partitions and metal linings in the amplifier cabinet. The terminal of the transformer secondary winding to which the neutralizing condenser is connected is dependent upon the direction of the windings. This can be determined by trial, the connections to the secondary terminals being interchanged or the direction of the winding reversed if necessary.

The proper capacity or size for this neutralizing condenser is dependent upon the capacity between the grid and plate of the amplifier tube and also upon the ratio of the number of turns in the amplifier transformer windings. Hazeltine gives the relation between these quantities as $\frac{N_1}{N_2} = \frac{C_2}{C_1}$

where N_1/N_2 is the ratio of turns on the primary and secondary windings.

C_1 is the capacity between the grid and plate of the tube and C_2 is the capacity of the neutralizing condenser. A ratio of transformation of 1 to 1 is found in many radio-frequency transformers. In this case the neutralizing condenser has the same capacity as that between the tube elements, which is usually about 10 or 15 micro-microfarads. It may be seen, therefore, that this capacity can be secured by using two very

small metal plates or two very small and short cylinders which slide within one another though insulated from each other.

The adjustment of each neutralizing capacity is made experimentally by tuning in a very strong signal and then disconnecting the filament of the tube whose capacity is to be adjusted, but leaving the tube in its socket. If the neutralizing capacity is not correct, the circuits on each side of the tube will have capacity coupling which will transmit the signal. The neutralizing capacity is then adjusted until the signal disappears.

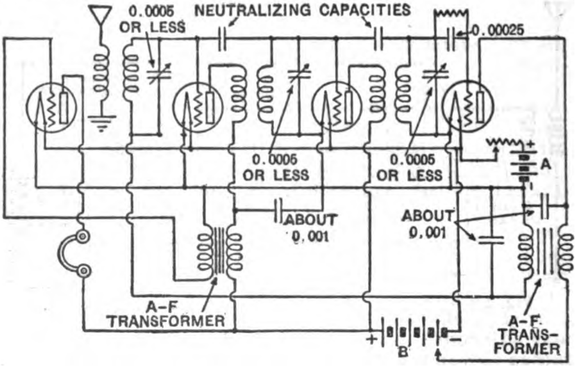


Fig. 42—Diagram of Reflex Neutrodyne.

This neutrodyne circuit is most effective when care is taken to have sharply tuned radio-frequency transformers, though the adjustments required are more complicated if sharper tuning and greater selectivity are attained.

There is no reradiation from the antenna of a neutrodyne receiver even when a regenerative circuit is used with the detector tube. Amplifier tubes may be used throughout, the choice of A and B batteries being determined by the type of tube employed as in any ordinary receiving set.

Flewelling Circuit.—A circuit which is interesting for the radio experimenter is that shown in Fig. 43 and which has been called the Flewelling circuit. It is essentially a regenerative receiving circuit to which some auxiliaries are added. Its behavior is very much like the Armstrong super-regenerative circuit and in fact it probably makes use of super regeneration in its operation. The principal tuned circuit is identical with that of a single circuit regenerative receiving set. There is also a feedback or tickler coil connected in the plate circuit and coupled with the inductance of the tuned circuit to give regeneration. The antenna and ground

connections are brought to the two terminals of the tuning condenser C_L. The additional apparatus required consists of three fixed condensers of 0.006 microfarad capacity each, and a high resistance which may be a grid leak of 0.5 megohm. In addition it is necessary that the grid leak resistance used with the customary grid condenser be a variable one.

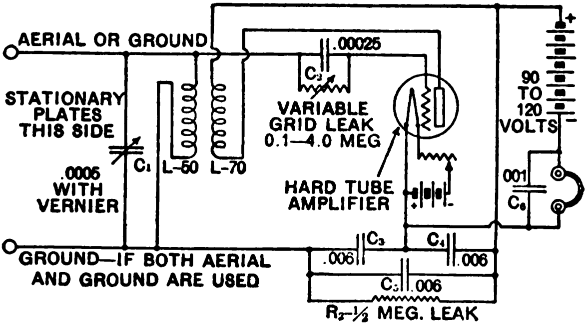


Fig. 43—Diagram of Flewelling Circuit.

When the circuit is first set up, the condensers C_3, C_4, and C_5 can be omitted, a short-circuiting wire being connected in place of the condenser C_3. Without these condensers the circuit is simply an ordinary regenerative circuit, and signals should be received as with such a circuit before connecting in the additional condensers. After connecting these condensers the operator should hear a steady singing or high-pitched whistle in the telephones. The amount of amplification secured depends upon the pitch of this whistling sound. This pitch is controlled by changing the resistance of the grid leak R_1. For this purpose it is convenient to have a variable grid leak having a resistance of from 0.1 to 4.0 megohms. It is possible to purchase variable grid leak resistors or one can use a piece of paper or fiber on which a mark is made with a soft pencil or with India ink. When the proper adjustment is obtained, the whistle should have a high pitch which is just barely audible. While somewhat greater amplification is obtained with a lower pitch, the whistle is correspondingly more noticeable and interferes with satisfactory reception. If the tone is too low or prominent, the resistance of the grid leak should be increased. If the pitch is too high, the resistance should be decreased. If the grid leak is made by a pencil or ink mark it is likely to change with changing atmospheric conditions, though it can be protected by clamping between pieces of glass or mica.

The sizes of the condensers C_3, C_4 and C_5 are not critical, the most critical part of the circuit being the

grid condenser C_2 and its grid leak resistance. When properly adjusted this circuit is extremely sensitive, and it has been reported that signals are sometimes received with the ground connection only, without any ordinary antenna. If the circuit sings or whistles when tried alone and becomes silent when the antenna is connected to it, a series condenser should be connected in the antenna circuit.

If a VT-2 tube is used, it is desirable to have a "B" battery of 120 volts. If a WD-11 tube is used, 45 volts in the plate circuit will be sufficient.

The advantage of this circuit is its extreme sensitivity. It has the disadvantage of being extremely difficult to adjust properly, and in addition has the objectionable property, possessed by all super-regenerative circuits, of interfering seriously with the reception of signals by others who operate receiving sets nearby. On the latter account it is not to be recommended for continuous use, but is an interesting circuit for trial and experimentation.

Reinartz Circuit.—The Reinartz receiving circuit is shown in Fig. 44. This is a circuit in which the feedback or tickler action is secured by connection to the coil which also forms part of the tuned circuit. A condenser is also connected between the plate of a detector tube and the antenna. The antenna circuit itself is not tuned. The antenna may therefore be much longer

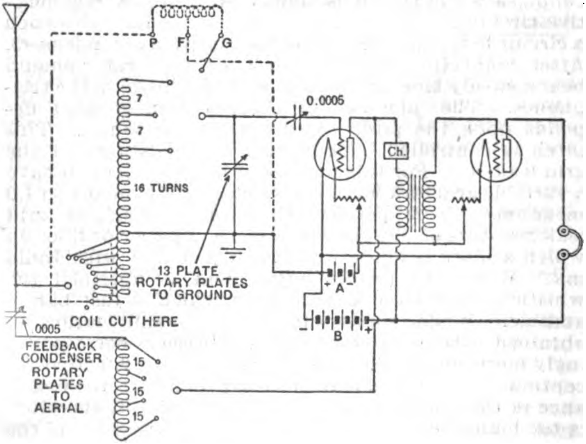


Fig. 44—Diagram of Reinartz Circuit.

than is ordinarily possible when it must be tuned to the received signals. The tuning of the secondary circuit is relied upon to secure selectivity. The circuit is shown in diagrammatic form in Fig. 45. In actual use

it is convenient to have a pair of taps brought out from the tuning inductance to three separate switches, as shown in Fig. 44. The coil can be wound continuously on a single form and cut into two parts at a point near the middle, as shown in the figure. The so-called "spider web winding" has been found by many experimenters to be convenient, since the wires to the switch contacts can be brought out in a compact way. If this form of winding is used, eighty-five turns of No. 26 single cotton-covered wire should be wound on a nine-spoke wheel, thus forming a coil 5 inches in outside diameter and having an open center 2½ inches in diameter. A coil thus constructed will enable the receiving set to cover a range from 130 to 360 meters. If it is desired to receive longer wave signals, a proportionately larger number of turns may be used all along the coil, or a loading coil may be inserted, as shown at P, F, and G of Fig. 44. This figure also shows the connections to a single amplifier tube through an audio-frequency transformer. The insertion of a radio-frequency choke coil at the point marked Ch. in the plate circuit of the detector tube will serve to increase the strength of the signals in case the distributed capacity of the primary winding of the amplifier transformer is large.

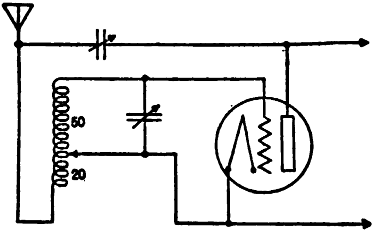


Fig. 45—Schematic Diagram of Reinartz Circuit.

In actual use this circuit is quite similar to the ordinary single circuit regenerative receiving set, regeneration being here controlled by means of a condenser connected to the antenna. The setting of this condenser does not change very much with wave length. The use of this method of feedback also tends to minimize the effect of the capacity between the circuit and the hand of the operator. In sensitivity the circuit is probably about the same as the ordinary regenerative circuit using tickler feedback. It has the disadvantage of causing reradiation and thus interfering to some extent with the reception of signals at other receiving stations nearby.

ARMSTRONG SUPER-HETERODYNE CIRCUIT

This circuit was originally described by E. H. Armstrong in an article entitled "A New Circuit of Short Wave Amplification," published in the Proceedings of the Institute of Radio Engineers for February, 1921. Additional notes on its operation were given by C. R. Leutz in an article entitled "Notes on a Super-Heterodyne," published in the magazine QST for December, 1922. The circuit diagram is given in Fig. 46. The antenna and secondary tuned circuit are identical with those ordinarily used in radio reception. The super-heterodyne circuit is useful chiefly for receiving short wave radio signals. Fundamentally, it transforms the received signals of extremely high frequency to a lower frequency which can be more easily amplified. The lower frequency currents after amplification are rectified by a detector tube and made audible in the telephone receivers.

The transformation of the high frequency currents to a lower frequency is accomplished by means of a heterodyne, which for most satisfactory use should be kept separate from the receiving set proper. This separate heterodyne is actually only a continuous wave generating set of low power which will generate current of a frequency nearly the same as that of the incoming signal. This separate heterodyne is coupled to the secondary circuit of the receiving set. For receiving 250 meter (1200 kilocycles) signals the separate heterodyne should be adjusted to generate a current of 1300 kilocycles (approximately 231 meters). A suitable circuit for this separate generating set is given in Fig. 47 and is described in more detail in Chapter 5, in connection with Fig. 8. Any amplifier tube can be used in this circuit, which is, in fact, equivalent to the secondary of a regenerative receiving circuit.

The first electron tube is a detector or rectifier tube which gives in its plate circuit, a current having a D.C. component with the beat frequency component superimposed upon it. The tuned circuits in the plate circuit of the first tube and the grid circuit of the second tube are adjusted to resonance with the beats (for example, 100 kilocycles or 3000 meters) produced by the received signals and the super-heterodyne. When once adjusted these two circuits can be left alone.

The next three tubes shown in the circuit, Fig. 46, are radio-frequency amplifier tubes with resistance coupling between the several stages. The next to last tube is another detector tube. The last tube is an audio-frequency amplifier. By using hard or high-vacuum tubes both as amplifiers and detectors, the connection to the batteries is simpler and the adjustments required are less complicated.

As a whole, the circuit is rather difficult to adjust when it is first being set up, but after this its use is

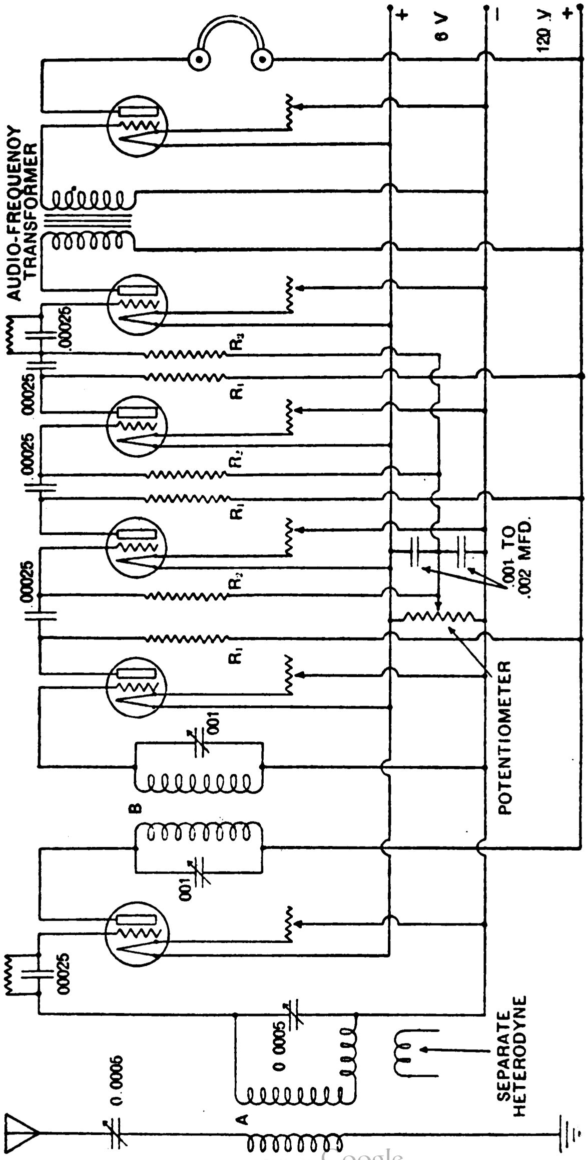


Fig. 46—Diagram of Super-Heterodyne.

simple, the adjustments required being the retuning of the antenna and secondary circuit to the frequency of the waves which it is desired to receive and adjusting the separate heterodyne to give the beat frequency for which the amplifier is originally tuned. The coupling between the separate heterodyne and the secondary and the strength of the current generated by the heterodyne set should be brought to the best value, though this condition is not at all critical. The greatest possibilities of this circuit are secured when four to eight tubes are used as radio-frequency amplifiers. It gives particularly good amplification of extremely weak signals and is very selective. If the coupling to the super-heterodyne is kept small there is very little reradiation and thus little interference is caused to nearby receiving stations. The use of radio-frequency amplification serves somewhat as a filter against stray noises. By transforming the incoming signals to the currents of a lower frequency it is possible to avoid the difficulty of radio-frequency amplification on short waves where the tube capacities cause trouble.

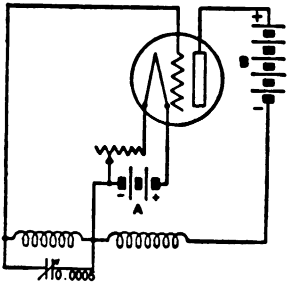


Fig. 47—Separate Heterodyne.

It is desirable to completely shield this receiving set, preferably by shielding separately the first detector tube, the radio-frequency amplifier and the last detector tube. This can be done by mounting these groups of tubes in boxes or on separate panels and lining these boxes with sheet copper. Care should be taken, of course, to avoid short circuits where the lead wires enter the boxes. In order to avoid back coupling from the current in the telephone cord it is desirable to cover it with woven copper braid which is connected to the shield enclosing the last tube.

The following details apply to Fig. 46:

R_1 = 10,000 to 100,000 ohms (see page 25 of Chap. 2).

R_2 = grid leak resistance, ½, 1 or 2 megohms.

The coupling between the separate heterodyne and the secondary of the variocoupler may be obtained by keeping the separate heterodyne on the same table or in the same room with the variocoupler. The two coils marked A are the primary and secondary of a variocoupler. For dimensions, see Table 2, page 14 of Chap. 2.

The coupling coils B must each have such value of inductance that they will, with the condenser, tune to the frequency to which it is desired to heterodyne the incoming signals. Honeycomb coils of 300 turns each are satisfactory if 3000 meters is used for the intermediate wave length.

USE OF JACKS IN A TWO-STAGE A. F. CIRCUIT

In the diagram shown in Fig. 1, X and Y are double-circuit jacks, and Z is a single-circuit jack. The double circuit jack serves the purpose of facilitating the connection of headphones to the detector circuit and automatically connecting the detector circuit to the first stage of audio-frequency when the telephone plug is withdrawn. This action is accomplished at X. Double-circuit jack Y serves the purpose of enabling one to use the first stage of audio-frequency amplification and cutting out the following stages, and then automatically connecting the second stage to the rest of the circuit by simply removing the telephone plug. These jacks do not automatically control the lighting of filaments, this being done by means of individual rheostats on the tubes. A single-circuit jack is sufficient on the last stage.

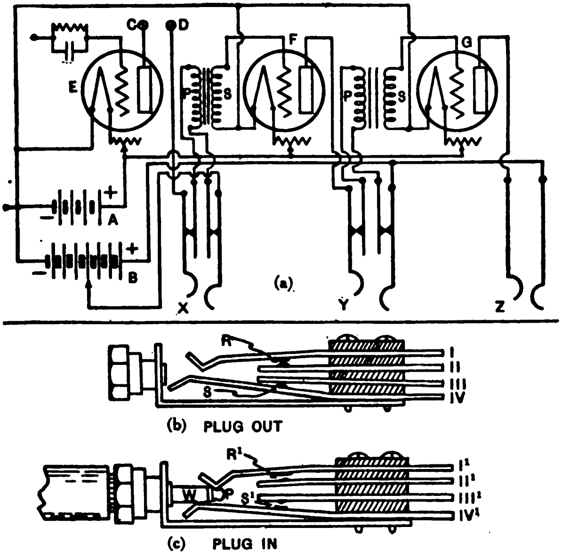


Fig. 1—Use of Jacks in Detector and First and Second Stages

It is highly important that the contact points in each of the jacks function properly. In Fig. 1 (b) is shown a double-circuit jack with the contact points touching at R and at S, as is the case when the telephone plug is withdrawn from the jack. When the contact points are touching, the circuit is as follows: From plate of detector into prong I, out of prong II to one primary terminal of the audio transformer, from the other primary terminal into prong III, out of prong IV to

the positive terminal of the B battery. This arrangement throws the primary side of the transformer into the circuit, thereby linking the detector stage to the following stages of audio-frequency.

In Fig. 1 (c), the telephone plug is shown inserted, thereby spreading prongs I′ and IV′ apart and breaking the contact at R′ and S′. The circuit now is as follows: From detector plate into prong I′, through tip of plug, P, to phones, back through collar of plug W, and out through prong IV′ to the positive side of the B battery. This arrangement short-circuits the detector tube directly to the phones, cutting out the stages following.

To use the circuit shown in (a) as non-regenerative, connect terminals C and D together. If regeneration is to be used, connect terminal C to one terminal of a variometer (or tickler-coil), and terminal D to the other terminal of the variometer (or tickler-coil).

GRIMES CIRCUIT

In the October issue of Radiofax, two diagrams of the Grimes circuit were presented for the purpose of showing the use of jacks in that circuit. In the plate circuits of the first tube in each of the diagrams a solid wire is shown connecting the lower end of the radio-frequency transformer with the filament. This wire should be broken and a fixed condenser of 0.001 microfarad capacity inserted. As the diagram now stands, there is a short circuit across the A and B batteries. These errors occured during the process of making the drawings for the cuts. A corrected sheet is being sent with this issue.

A closed circuit jack must be used in place of the one marked "2 R. F. and 2 A. F." in Figure 2, so that a complete path is offered to the current from the B battery to the plate when the phones are removed.

CHART FOR DETERMINING INDUCTANCE AND WAVE-LENGTH RANGE OF COILS

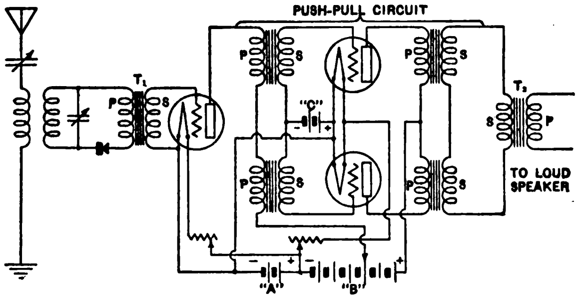
For those who like to design and build their radio receiving sets and who want a quick method of making calculations, we have published a chart which makes it possible to determine the wave-length range of any tuner in a few seconds. If you know the number of turns on the coil and its diameter, and the size of the variable condenser, a glance at the diagram will give the wave-length range over which this combination will function.

The chart is 6¾x10½ inches, folded to standard Lefax size and punched. Price, with full instructions, 15 cents. Address Lefax, 9th and Sansom Streets, Philadelphia, Pa.

PUSH-PULL AMPLIFIER

The idea generally held by the layman is that radio is an extremely new thing. This is wrong; it would be better for them to understand that the extremely new thing about radio is the public interest in it. The first DeForest patents were granted in 1908, the Armstrong patents in 1914. The Push-Pull Amplifier patent, the subject of this article, was granted to Mr. E. H. Colpitts, of the Western Electric Co., in February, 1915.

This amplifier was designed primarily to act as a distortionless repeater on telephone lines, and its adaptation to radio uses came later. In the words of the patent papers (No. 1,128,292), "Its object is to improve the quality of transmission by producing in the output circuit electric waves free from distortion with respect to the input waves." No claims are made for increased amplification, this being practically of the same value as that obtained with the usual single-tube amplifier employing the same type of tube. Increased volume is obtained, however, by means of this circuit, as the output of the two tubes combine, as explained below.



Transformers built especially for use in the push-pull amplifier are not generally available, although several have been advertised. Ordinary audio-frequency transformers may be used, however, as indicated in Figures 1 and 2 of this article. Two transformers are used in series for the input, and two more arranged similarly for the output. Any of the good transformers on the market may be used. The important thing is that the two transformers in each pair must be identical.

The illustration on page 48 is a photograph of one of these outfits. At the left of the picture is shown the tuning apparatus connected to a crystal detector. The output of the detector circuit is then passed through an audio-frequency transformer to a usual vacuum tube amplifying circuit, and thence to the push-pull ampli-

fier. The arrangement of apparatus in the picture is the same as that in the wiring diagram, Fig. 1. Fig 1, however, shows an innovation in connection with this circuit, in the use of another audio-frequency transformer connected between the output of the push-pull amplifier and the loud speaker. This transformer is used inverted, that is, the current is put into the high resistance winding (generally marked secondary) and taken out of the low resistance winding (marked primary). In other words, it is used as a step-down transformer. The use of this transformer increases the volume output of the loud speaker or phones several times. The reason for this is as follows: It is generally known that the efficiency and consequently the output of any system comprising a generator and a receiver of energy is greatest when the impedances of the generator and receiver of energy are equal. The impedance of the loud speaker (or receiver of energy) is generally low compared with that of the secondaries (in series) of the output transformers of the push-pull amplifier. By introducing this step-down transformer, the high impedance secondaries in series feed into the high impedance winding of the added transformer, and the low impedance winding of this latter feeds into the low impedance of the loud speaker.

It seems that the writers of articles on the push-pull amplifier have been content to omit explanations of its operations and as to why it eliminates distortion. Consider Fig. 2. This shows the output side of the push-pull amplifier, consisting of the two plate circuits and output transformers connected in series. The steady plate currents of the two tubes are in opposite directions through the transformers Let us suppose that the current flowing from b to a is suddenly decreased slightly. This will cause a slight decrease in the magnetic field set up by this current, so that less opposition will be offered to the flux set up by the current flowing from c to d. The effect in the secondaries of the transformers will be the same as if the current from b to a had not decreased in value, but as if the current from c to d had increased in value. A decrease in current in the primary of one transformer, then, adds to the effect of the current in the other.

This can be understood by remembering that when the potential of the grid of one tube is positive, that of the other is negative. A negative potential on the grid of a tube causes a decrease in plate current, while a positive potential causes an increase. These occur simultaneously, so that the addition of the two effects results in a magnetic field in the two transformers which is in excess of that which would exist if only one tube were used. The current induced in the secondaries is consequently greater.

Moreover, since the characteristics of the tubes are not perfectly linear, the decreases in one tube are slightly less than the increases. This unsymmetrical action results in a certain amount of distortion, which is the same in both tubes; but by adding the decreases in one direction to the increases in the other direction, certain elements of the distortion cancel each other.

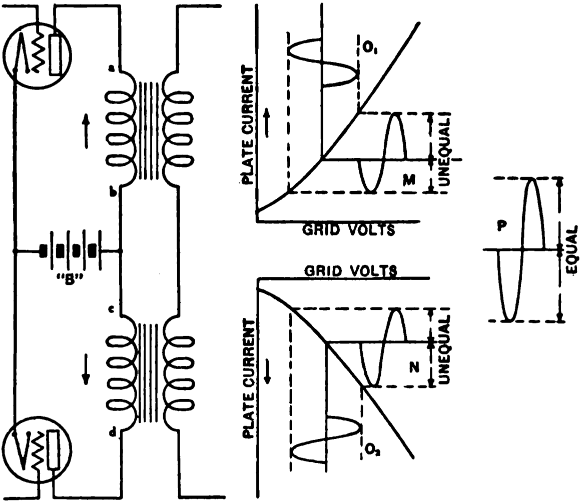


Figure 3 is an attempt to illustrate this graphically. It represents the characteristic curves of the two tubes, drawn in such a way that the axes of plate current are positive in the same direction as the flow of current through the primaries of the transformers. The upper oscillation, O_1, indicates that the grid of tube 1 is negative at the same instant that the grid of tube 2 is positive, as indicated by the lower oscillation, O_2. The output currents of the two tubes are shown at M and N, and if these two are added, the result is a symmetrical oscillation, P, of the same frequency but of greater amplitude. The currents M and N do not really exist separately. The voltages which tend to produce them are generated separately and, when combined, produce the current, P.

We have had the good fortune of testing out the push-pull circuit with transformers that have been specially designed for it. Although the use of four ordinary transformers results in fairly good performance, better performance was obtained by using the special transformers, as these have been designed with the proper impedances required, and an added transformer is not required between the output and the loud speaker.

THE CRYSTAL DETECTOR

The comments in Radiofax on the field of the crystal detector have caused considerable interest and requests have been received urging that we prepare an article giving all facts of scientific and practical interest, that are known regarding the use of all kinds of crystal detectors.

Work has already been started on such an article, and we hope to be able to insert it in a near-future issue of Radiofax.

A great amount of investigational work has been done on crystals because they were the best detectors available for a long period of time. The data resulting from the efforts of many scientists is scattered through various books and pamphlets which are now being used by us in the preparation of the forthcoming article. We believe our readers will be surprised to find that the unassuming crystal can display so many points of interest and still defy all efforts to explain why it rectifies.

BOOK REVIEW

The Outline of Radio by John V. L. Hogan, published by Little, Brown and Co., Boston.

A host of books on radio have appeared in the last two years. Many of them have past into oblivion because they lacked dependability. Others were too technical for the average radio fan although as scientific works they were excellent. In the keen competition for survival, the multitude of authors each strove to handle the subject from a slightly different angle, until it seemed impossible to conceive of any method of presentation having been overlooked.

Never the less, Mr. Hogan recognized the need for another book on radio, to serve a purpose entirely distinct from that of any existing works, and "The Outline of Radio" is the result of his effort to fill this gap.

It is extremely difficult to describe in a few words the text matter of this book and to convey any idea to the public of its great educational value. It presents to the reader just enough of the historical, scientific, engineering and economic sides of radio to give a broad comprehensive understanding of the subject, without the introduction of a single uninteresting paragraph.

Combined with a practical reference book, it rounds out the knowledge of the radio enthusiast and increases his appreciation of the magnitude and utility of the art of wireless communication. It also facilitates the understanding of many seemingly involved technical points by presenting them to the reader from a new viewpoint.

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

For the benefit of those who have difficulty in visualizing, from circuit diagrams, what the panel layouts would be, these semi-constructional drawings are given. No attempt is made at giving sizes and exact spacing of the holes that must be drilled, on account of the lack of uniformity in the radio parts obtainable on the market. Primarily, these drawings are intended to give readers an idea of the relative positions of the instruments and to show the simplest and most practical arrangements. All instruments are grouped so as to insure short leads in wiring and minimum mutual induction.

Circuit 1, the single-circuit regenerative receiver, is characterized by its sensitivity and long-range receptive powers, although limited in selectivity. This is an excellent circuit to employ where there are not several local broadcasting stations operating at the same time. If greater selectivity is desired, Circuit 2 may be used. In this case, the rotor of the coupler is used as the secondary coil, giving loose coupling, and therefore greater selectivity than Circuit 1 provides. A variometer is used for tuning the plate circuit, thereby producing regeneration, instead of using the coupler rotor for this purpose, as is done in Circuit 1. Circuit 3 has the same receiving properties as Circuit 2. All of these circuits may be counted on to receive, conservatively speaking, over distances of several hundred miles, and under favorable conditions a range of 1,000 miles may be reached. Circuit 4 is the standard 3-tube, 3-circuit regenerative receiver that has become so popular on account of its long-range ability, its pleasing volume for loud-speaker use, and its extreme selectivity. The condenser C may be of the 23- or 43-plate type. Any well-made variocoupler will prove satisfactory at V. A variometer is used in the grid circuit at V_1, and another is used at V_2 in the plate circuit, producing a well-balanced circuit.

Jacks are used in this circuit after the detector, first A.F. stage and second A.F. stage, as shown at J_1, J_2, and J_3. The two center prongs of the regular 2-circuit jacks, such as shown at J_1 and J_2, are connected to the input of the following A.F. transformer.

It will be noted that the two variometers are placed as far apart as conveniently possible, to minimize mutual induction. The audio-frequency transformers TT should be mounted at right angles to each other, for the same reason.

The following general rules in setting up any circuit should be carefully followed: Be sure to remove the greasy residue left after soldering connections. This is very often the cause of inoperative jacks, variocouplers,

variometers, and any instrument on whose shaft or bearings this greasy material is left. It is inadvisable to solder connections to a fixed condenser unless it is so made as to withstand the soldering heat. See that all joints are tight, and use as short and as unparallel leads as possible in making connections between instruments. It is best to allow an average distance of about 4 inches between the centers of all parts.

In laying out the panel of a set, the position of each instrument, with the necessary holes to be drilled, should be carefully diagrammed on a piece of paper; then, laying this template on the panel, it is comparatively easy to mark off the centers of the holes and to drill them accurately.

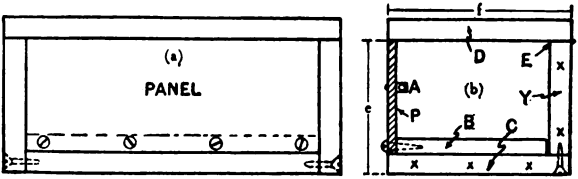


Fig. 1

Figure 1 illustrates an easy way of building a cabinet to contain the panel and its base. The front view of the cabinet and panel is shown at (a). The end view at (b) shows how panel P is mounted on base B, the two forming a complete unit in themselves, which may be readily placed in or removed from the cabinet. The panel base B rests on the cabinet base C, and the panel with its base is prevented from sliding out by means of the small angle bracket A fastened to the inside of the panel and which is flush with the end of the panel. This angle A is engaged by a stove bolt passing through the side of the cabinet. The cover of the cabinet is hinged at E, permitting easy access to the instruments within the case. The end of the cabinet, designated by (e f), should be fastened in place by screws at positions XXX in base C and XX in back Y. This arrangement provides a very rigid construction for the cabinet.

If the set-builder desires to use the baseboard of the cabinet as the base of the set itself, the panel may be readily mounted on the base by means of three angle-brackets, as shown in Fig. 2. This permits the full height of the panel to be used for mounting instruments, whereas in the plan used in Fig. 1 about a half-inch of the height of the panel is used for screwing it to the base B.

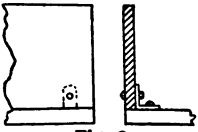
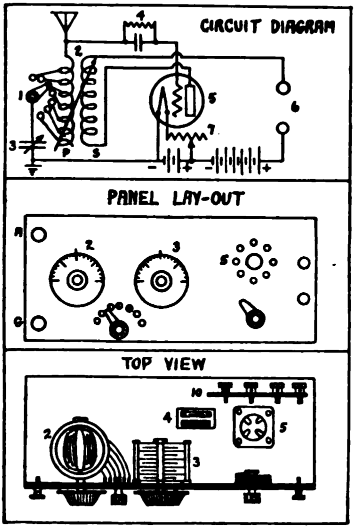


Fig. 2

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

1.—SINGLE-CIRCUIT REGENERATIVE RECEIVER

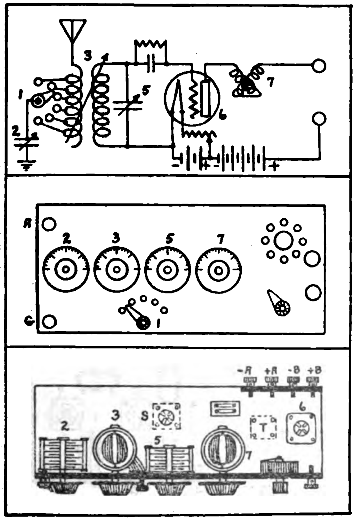


1 = Switch knob.
2 = Variocoupler.
3 = .001 condenser.
4 = Grid leak and condenser.
5 = Detector.
6 = Phones.
7 = Rheostat.

A = Antenna.
G = Ground.
2 = Coupling control.
3 = Condenser control.
5 = Peep-holes, detector tube.

4 = Grid leak and condenser, .00025 mfd. and 2 megohms.
5 = Tube socket.
10 = Small upright panel for battery binding posts.

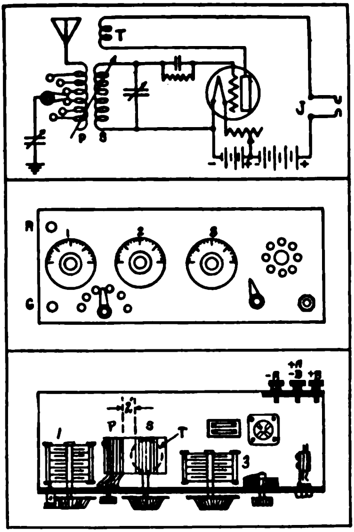
2.—TWO-CIRCUIT REGENERATIVE RECEIVER



1 = Switch knob.
2 = .001 condenser.
3 = Variocoupler.
5 = .0005 condenser.
6 = Detector.
7 = Variometer.

A panel 6–8″ high and 28″ long will prove satisfactory. The arrangement shown permits easy access to the terminals and contacts. To save space the instruments may be staggered. There is ample room for another socket S and transformer T.

3.—TWO-CIRCUIT RECEIVER USING TICKLER COIL FOR REGENERATION



The primary P and secondary S are loosely coupled, wrapped on the same tube 2" apart. The rotor is tickler coil T.

1 = Condenser control, 43 plates.

2 = Tickler control.

3 = Condenser control, 23 plates.

J = Single - circuit jack.

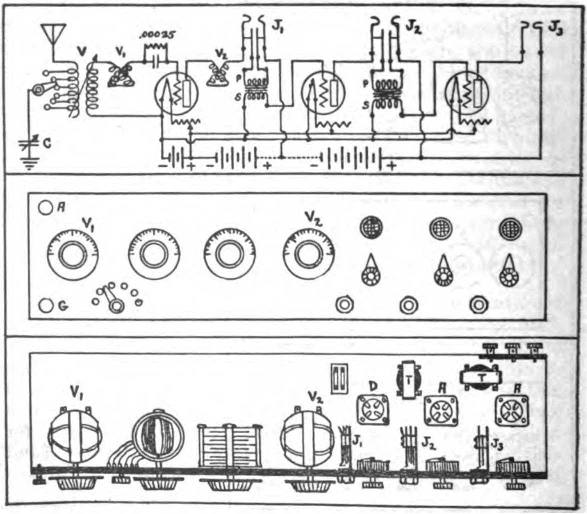
1 = .001 condenser.

3 = .0005 condenser.

.001 mfd. = 43 plates.

.0005 mfd = 23 plates.

4.—THREE-CIRCUIT REGENERATIVE RECEIVER USING TWO VARIOMETERS



RHEOSTATS FOR VACUUM TUBES

Since vacuum tubes operating on dry cells have appeared on the market, considerable confusion has existed among amateurs concerning the proper value of resistance to use in series with the filament when connected to various types of batteries.

The following table gives the values of resistance required. As an illustration of the use of the table we will consider the WD-11 tube. Normal current of 0.25 amperes flows through the filament when a voltage of 1.1 is impressed across the filament terminals. The resistance of the filament when hot is then, by Ohm's law, $1.1/0.25 = 4.4$ ohms. This value is given in the third column of the table. If a dry cell is used to light the tube, delivering a voltage of 1.5 volts, the total resistance which must be in the circuit to give the current a value of 0.25 ampere is $1.5/0.25 = 6$ ohms. Part of this resistance is in the filament itself, and the rest must be furnished by the rheostat. The rheostat must furnish $6 - 4.4 = 1.6$ ohms to allow the normal value of current to flow.

To be on the safe side, the resistance of the rheostat should be slightly higher than this value, say 2 ohms; but 2-ohm rheostats are not common on the market, so is is required that we use the next larger size. Too great a size must not be used, for although this will cut down the current to the proper value, the adjustment is not as critical. For instance, suppose we are using a 6-ohm rheostat. We require only 1.6 ohms, so that we shall be using only about one-quarter of the rheostat. It is obvious that slight changes in the rheostat setting will produce rather large changes in the resistance and in the filament current.

Tubes may be connected in series or parallel. The values in the table have been worked out for both cases, so that if the amateur happens to have on hand a storage battery and wishes to use it to light up tubes designed for lower voltages, he may do so by connecting the tubes in series. It is clear that the current in each tube when connected in series will be the same. The tubes in this case must have similar characteristics.

For tubes connected in parallel, the resistance required in the rheostat to give the normal value of current is given by $R = (V - E) \div (I n)$, in which R is the resistance in ohms required, V is the voltage of the battery in volts, E is the rated normal filament voltage, I is the rated normal filament current, and n is the number of tubes in parallel.

For tubes connected in series, the formula is $R = (V - nE) \div I$.

In using dry cells to light up WD tubes, greatest economy, that is, longest life, of the batteries is obtained when they deliver about 0.125 ampere each. Thus,

for one WD tube, use 2 cells in parallel; for two tubes, 4 in parallel, etc.

To furnish 4.5 volts for the UV-199 tube, three 1.5-volt cells may be connected in series.

The rated normal current for these tubes is only 0.06 ampere and three in parallel would take only 0.18 ampere. In this case it is not necessary to connect the cells in parallel to obtain good economy.

	Rating		Fil. Re-sist.	Batt. Volts	No. of tubes	Total Cur-rent	No. Cells Required	Resist. Required	Size Rheostat	Tube Con-nec-tions
	Volts	Amps								
WD-11	1.1	0.25	4.4	1.5	1	0.25	2 Parallel	1.6	6	
WD-12				1.5	2	0.50	4	0.8	6	P
				1.5	3	0.75	6	0.5	6	P
				6.0	3	0.25	St. batt.	10.8	12	S
UV-199	3.0	0.06	50.0	4.5	1	0.06	3 Series	25.0	30	
C-299				4.5	2	0.12	3	12.5	20	P
				4.5	3	0.18	3	8.3	12	P
				6.0	1	0.06	St. batt.	50.0	60	P
				6.0	2	0.12	"	25.0	30	P
				6.0	3	0.18	"	16.7	20	P
				6.0	2	0.06	"	0	6	S
UV-200	5.0	1.0	5.0	6.0	1	1	"	1.0	6	
C-300				6.0	2	2	"	0.5	6	P
				6.0	3	3	"	0.3	6	P
UV-201	5.0	1.0	5.0	6.0	1	1	"	1.0	6	
C-301				6.0	2	2	"	0.5	6	P
				6.0	3	3	"	0.3	6	P
UV-201A	5.0	0.25	20.0	6.0	1	0.25	"	4.0	10	
C-301A				6.0	2	0.50	"	2.0	6	P
				6.0	3	0.75	"	1.0	6	P
215-A	1.1	0.25	4.4	1.5	1	0.25	2 Parallel	1.6	6	
				1.5	2	0.50	4	0.8	6	P
				1.5	3	0.75	6	.5	6	P
				6.0	3	0.25	St. batt.	10.8	12	S
216-A	6.0	1.1	5.5	6.0	1	1.1	"	0	6	
				6.0	2	2.2	"	0	6	P
				6.0	3	3.3	"	0	6	P
VT-1	2.5	1.1	2.3	6.0	1	1.1	"	3.2	6	
(203-B)				6.0	2	2.2	"	1.6	6	P
(J)				6.0	3	3.3	"	1.1	6	P
				6.0	2	1.1	"	0.9	6	S
VT-2	6	1.35	4.5	6.0	1	1.35	"	0	6	
(205-B)				6.0	2	2.70	"	0	6	P
				6.0	3	4.05	"	0	6	P

PRINCIPLES OF OPERATION OF LOUD SPEAKERS

The most common type of loud-speaking reproducer is that operated on the **electro-magnetic** principle, in which a metallic diaphragm is placed over the poles of a permanent magnet. Two coils of very fine wire are arranged on the pole pieces of the magnet and are connected to the receiving set. (Fig. 1.)

The magnet in this reproducer is very strong, as can be seen by trying to lift the diaphragm from the pole pieces. The diaphragm is under a constant strain or tension, due to this magnetic pull. When electrical energy from the receiving set passes through the coils on the pole pieces, the magnetic pull on the diaphragm is varied in accordance with the strength of received signals. It is this diaphragm movement that causes sound waves to be set up, thus reproducing the sounds coming through the receiving set.

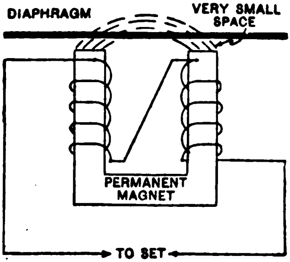


Fig. 1

This type of reproducer demands, for best operation, that the diaphragm be placed as closely as possible to the poles of the magnet without touching them. While volume sufficient to fill an ordinary sized room may be produced, the electro-magnetic type of loud speaker should not be overworked in an attempt to produce volume capable of filling a large auditorium. If this is attempted, the powerful signals may cause the diaphragm to be drawn upon the magnet poles, causing distortion or chattering. A number of loud speakers built on this principle are provided with an adjustment for changing the distance between diaphragm and magnet poles, thereby avoiding tendency toward chattering or noisy reproduction.

Sound reproducers constructed on the **electro-dynamic** principle are capable of operating efficiently over a very wide range of electrical energy received. In this type of loud speaker there is no strain or tension on the diaphragm when no electrical energy is received from the plate circuit of the receiving set. Instead of a permanent magnet, an electro-magnet is used whose field coil is connected to a 6-volt battery which supplies a current of about 1 ampere for this electro-magnetic field. An armature, which is a small coil of wire the shape of a ring, attached to the metal diaphragm, moves up and down in the ring air gap of the electro-magnet, which is cylindrical in shape. Fig. 2 illustrates this type of reproducer.

No magnetism is passed through the diaphragm, and it is therefore under no tension until current is flowing through the armature. There is no force tending to move this coil sideways, hence the danger of clinging to the pole pieces is eliminated, even when considerable electrical energy is passed through the armature from the receiving set. When a 6-volt storage battery is connected to the electro-magnet, a very strong magnetic field is created in the air gap between the two pole pieces. Inasmuch as the armature coil is not wound on magnetic material, there is no tendency for it to be attracted to the magnet.

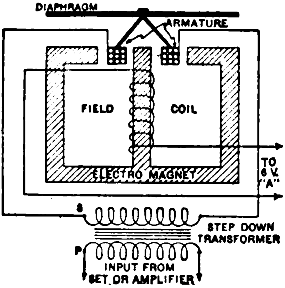


Fig. 2

When electrical energy from the receiving set starts to flow through the armature, a magnetic field due to this current is set up in the air gap, which reacts with the powerful field of the electro-magnet and causes the little coil (armature) to move **up and down**, causing the diaphragm to vibrate. The step-down transformer, shown in Fig. 2, is part of the loud speaker, and does not represent an additional piece of equipment. The diaphragm and the armature rigidly attached to it can only be made to move by the incoming electrical energy from the plate circuit of the receiving set, and it is this movement that causes the diaphragm to create sound waves. By reason of this principle of construction, the sound waves produced are in accord with the energy received by the diaphragm armature. In this type of reproducer, if distortion occurs, the source of disturbance should, as a rule, be looked for in the receiving set.

Inasmuch as the armature is not required to move against the constant pull of a permanent magnet, it is sensitive enough to respond to very small currents passing through it, and thus the movement of the diaphragm is limited only by its own elastic limit.

Another type of efficient loud-speaking reproducer is that operated on what is known as the **balanced armature** principle. In this type the diaphragm and moving parts of the receiver unit respond to all frequencies in the broadcasting range without appreciable distortion. The better type of loud speakers on this principle have receivers sensitive to very weak currents and capable of carrying comparatively heavy currents without the armature chattering against the pole pieces.

The operation of this type of loud-speaking units, as shown in Fig. 3, is as follows:

Signal currents from the receiving set pass through the step-down transformer and into the winding A. This winding is wrapped on a core which is pivoted at P. The balanced armature and its winding lies in the magnetic field of a high-grade permanent steel magnet whose poles M and N branch out over both ends of the armature. The incoming current through armature A sets up a magnetic field around the windings, which field reacts with that of the permanent magnet and causes a pivot action which is transmitted by rod R to the diaphragm. These diaphragm vibrations, in unison with the pulsating current through the armature windings, give rise to the sounds created by the air waves passing out through the horn.

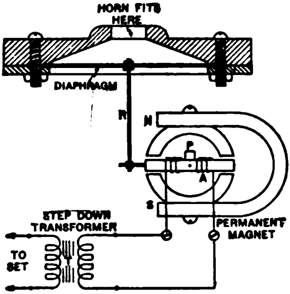


Fig. 3

The purpose of the transformer T is to match the impedance of the loud-speaking unit (approximately 2000 ohms) with that of the plate circuit of the receiving set amplifier tubes, 15,000 to 20,000 ohms. It is the duty of this compensating transformer to prevent losses in efficiency by balancing impedances.

Still another type of loud speaker is one recently developed and known as the "relay type." Its construction is similar to that of a polarized telegraph relay. Four pole pieces, each carrying a coil, are grouped about a thin iron armature. The pole pieces receive their magnetism from magnet M in Fig. 4.

The coils are so connected that a simultaneous attraction is exerted by diametrically opposite pole pieces. The diaphragm is made of corrugated aluminum and operates through a rod actuated by the armature.

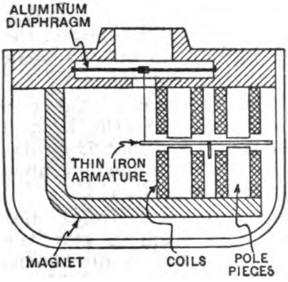


Fig. 4

The horn of a loud-speaking reproducer plays a considerable part toward securing perfect reproduction. The effect of the horn is dependent on the qualities of the diaphragm, inasmuch as the horn is a load on the diaphragm. A large load will produce a damping effect, eliminating the resonance of the diaphragm. The horn itself possesses definite points of resonance.

If the resonance of the diaphragm should occur at any of the resonance points of the horn, excessive vibration and noise frequently results. A longer horn tends to produce more uniform load at various frequencies. Length and shape of the horn modify signals to a great extent. A. Nyman, in a recent issue of the A. I. E. E. Journal, claims that the best reproduction for the horn type of loud speaker is obtained by employing a horn longer than ¼ the wave-length of the lowest available pitch. A horn type loud speaker with balanced armature and a horn approximately 2 ft. in length has been found to give excellent reproduction even of extremely low frequencies.

Not all of the efficient loud speakers use a long horn. There is another class of reproducer using the principle of reflected tone, and, instead of employing a continuous horn, have a break or air space between the narrow part of the horn and the section where the wide flare begins, which section is turned back on the first half of the horn. The narrow throat of the horn extends from the loud-speaking unit out into the reversed hollow chamber formed by what we may consider the latter half of the horn. This latter half is closed at one end, thus acting as a reflector of sound.

Figure 5 illustrates this arrangement. The loud-speaking reproducer R is supported at the center of the wide bell B. Fastened into this unit is a metal tube T which carries the sound waves back into the sound chamber C, where they are reflected in the direction of the arrows through chamber C into bell B, and out into space. There is an air gap of approximately ¼ inch at A. This serves the purpose of letting the muffled, harsh tones escape, and avoiding the stifled, crowded sound so common in a number of loud speakers on the market.

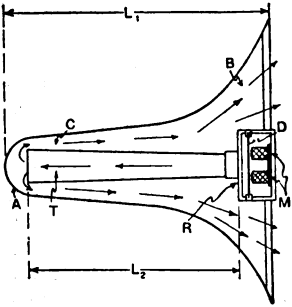


Fig. 5

The magnet poles at M may be adjustable so as to move them closer or farther away from the diaphragm D, thereby adapting the loud-speaking unit to weak or intense signals.

It was shown that two horns with lengths L_1 and L_2 are approximately equivalent to a single long horn with length $L_1 + L_2$.

Aluminum or mica diaphragms seem to give the best results, while horns made of wood or some other low vibrant material have been found to give the purest reproduction.

THE SUPERDYNE CIRCUIT

This circuit represents another effort to overcome the difficulties encountered in radio-frequency amplification on low wave-lengths, due to the internal capacity of electron tubes. In brief, it provides a means whereby the feedback through the tube is counteracted by an opposing feedback through a tickler coil with reversed connections. By this means it is claimed that resonant circuits can be used.

The circuit arrangement is given on the following page for the original four-tube set. It consists of one stage of radio-frequency, detector, and two stages of audio-frequency amplification. Both the grid and plate circuits of the radio-frequency tube are provided with means for tuning them to resonance. In ordinary tuned radio-frequency circuits the tubes will begin to oscillate and thus spoil the signal before complete resonance is attained. In the superdyne the proper adjustment of the reverse-connected tickler coil prevents oscillation and allows tuning to resonance, thus materially increasing the amplification.

There is nothing mysterious about the reversed connections, at least to anyone who has operated a regenerative set using a tickler coil. In such a set the signals increase in strength as the tickler coil is turned away from the right-angle position with relation to the stator winding. This is because the connections are so made that the two coils have the same polarity, and therefore, the greatest energy transfer between them is when the coupling is closest. If the two wires leading to the tickler be reversed it will be found that the coil no longer works the same way, for the polarity has been changed. When the proper reversed condition is attained it will be found that the greatest amplification occurs when the tickler coil is at right angles to the stator coil. In this position the reverse feed back is at a minimum, and the tendency of the tube to oscillate is at a maximum. In actual operation the tickler coil must be set at a position somewhat off from this minimum.

The superdyne circuit in its present form is best adapted to the reception of distant signals when used with a headset. It will operate a loud speaker very well over shorter range. No satisfactory way has been found to operate a headset in the detector circuit and still maintain the efficiency of the hook-up. The diagram given, therefore, shows jacks in the plate circuit of the audio-frequency amplifiers only.

The circuit will operate on a short indoor antenna. It offers an opportunity to those who are unable to install an outdoor aerial. An out-door antenna can of course be used and will give superior results. If indoor aerial is to be used it should be connected directly to

the grid end of coil L_2. The ground wire can remain in its usual position. The four primary turns are only used for outdoor antennas.

The specifications for the material needed for building the superdyne are as follows:

Coil L_1—Four turns No. 22 D. S. C. wire, wound over coil L_2, turns spaced ¼" apart.

Coil L_2—Forty-two turns No. 22 D. S. C. wire, wound on 4-inch diameter tube, tapped at 20th and 42nd turn. Length of winding, 1¼ inches; inductance 273 microhenries.

Coil L_3—Forty-six turns No. 22 D. S. C. wire, wound on 4 inch diameter tube, tapped at 25th and 46th turn. Length of winding 1¼ inches; inductance 264 microhenries.

Coil L_4—Total 36 turns, wound 18 turns on each side of a rotor 3⅝ inch in diameter. Wire size No. 22 D. S. C.

If rotor of the exact size specified cannot be obtained it would be much better to use a smaller rather than a larger size.

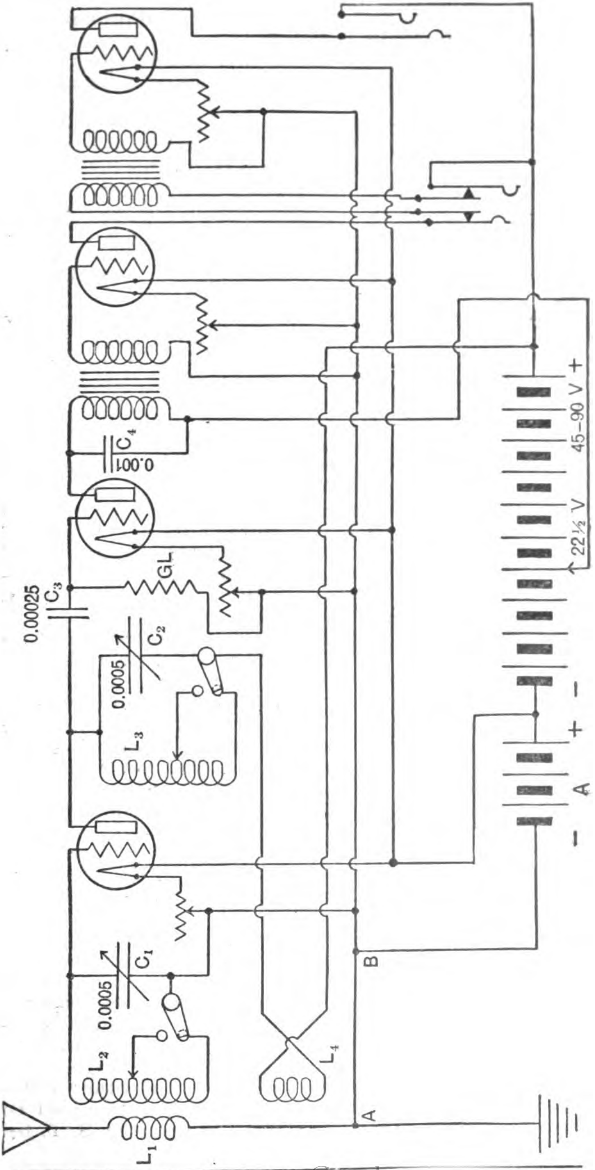
The abbreviation D. S. C. means "double silk covered." If wire thus insulated cannot be obtained, double cotton-covered wire may be used. The former, however, is superior in certain respects.

Condensers C_1 and C_2 are variable type with maximum capacity of .0005 mfd. They should be of good quality and have low leakage losses. With condensers of this size the tuning range when using the intermediate taps is 176 to 358 meters. When the entire coil is used the range is 310 to 660.

Condenser C_3 can have a capacity anywhere between .00018 and .00025 mfd. It is the grid condenser of the detector tube. Do not use a combination of condenser and leak.

Condenser C_4 is a bypass condenser. Its use is not essential. It will in some cases improve the results but this can only be determined by trial. The grid leak marked, GL, need not be used unless upon trial it appears to be desirable. It should in no case be connected across condenser C_3 in the usual way, for this would impress the high positive voltage of the B battery on the grid of the detector and entirely prevent the operation of the set. The proper method of connecting the grid leak is shown in the diagram. However, it would be wise to try connecting it to the positive side of the A battery before final assembly.

The wire connecting points A and B serves to ground the negative side of the A battery. This connection was not used in the original diagram as presented at the recent annual A. R. R. L. convention by C. D. Tuska, but it has been found that the addition of this wire tends to materially stabilize the set, although it may


C₄
0.001
0.00025
C₃
GL
C₂
0.0005
L₃
C₁
0.0005
L₂
L₁
L₄
A
B
+
45–90 V
22½ V
–
+
A
–

somewhat reduce its sensitivity. It would probably be wise to try the circuit each way.

It is claimed that the condition of the B battery has a vital influence on the operation of this circuit and that even one dead cell will prevent proper functioning.

Grounding the cores of the audio-frequency transformers may result in an increase in signal strength and diminution of capacity effects. To do this it is simply necessary to fasten a wire to the iron core of each transformer and connect the other end of the wire to the ground binding post. On most transformers it will be found possible to make this connection by loosening one of the screws holding the frame together, inserting the wire beneath it and re-tightening.

The following suggestions should be noted by any who plan to experiment with this circuit.

(1) The end of grid coil L_2 adjacent to the tickler must be connected to the filament in order to reduce the effective grid-to-plate capacity of the first tube.

(2) Be careful that there are no parallel grid and plate leads—keep them at right angles. Make all connections as short as practicable and use solder wherever possible.

(3) Provide a means for varying the distance between the shaft of the tickler coil and the adjacent end of coil L_2. If the tickler is set too close to the grid coil it will not function properly. The minimum spacing is ½ inch. After the best spacing is determined, the coil and tickler can be permanenly mounted.

Tuning of this circuit is not difficult after the function of each adjustment is understood. In general, it is as follows:—Set the tickler coil at an angle of 70 or 75 degrees with the stator winding.Set both condensers C_1 and C_2 at maximum (plates entirely enmeshed). Turn dials slowly, keeping the setting of both at all times identical. Turn them over the entire range. If the desired station is tuned in during this process, adjust dials to maximum intensity and then loosen tickler coupling to further increase signal strength. When tickler is moved it will be found necessary to readjust condenser C_1 slightly. Condenser C_2 is not thus affected and can be calibrated in wave-lengths as station after station is tuned in.

If in the first turning of the condensers the station wanted was not tuned in, set both condensers at maximum again. Then turn one a few degrees in advance of the other and maintain this relationship throughout another complete revolution. When properly constructed and operated this circuit tunes very sharply and dials should therefore be adjusted carefully.

A detailed account of the theory of other radio circuits and the difficulties the superdyne is hoped to remove is given in November 1923, issue of Q. S. T. by C. D. Tuska.

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

Three-Coil Honeycomb Circuit with Regeneration

A number of readers have requested from time to time that a circuit using honeycomb coils be shown in Radiofax. Fig. 1 is a diagram showing the use of three honeycomb coils in a regenerative circuit. The parts used in the construction of this set are as follows:

1.—Primary, 75-turn honeycomb coil.
2.—Secondary, 75-turn honeycomb coil.
3.—Tickler, 50-turn honeycomb coil.
4.—Double-pole, double-throw switch.
5.—43-plate variable condenser (.001).
6.—23-plate variable condenser (.0005).
7.—.00025 mfd. condenser and 2-megohm grid leak.
8.—Detector tube, UV-200.
9, 10.—Amplifier tubes, UV-201A.
11.—A.F. transformer, about 5:1 ratio.
12.—A.F. transformer, about 3½:1 ratio.
13, 14, 15.—6-ohm rheostats.
16, 17.—Double-circuit jacks.
18.—Single-circuit jack.
19.—.001 fixed condenser.
20.—Battery switch.

The double-pole, double-throw switch enables condenser 5 to be thrown into the circuit either in parallel with the primary coil at position A or in series at position B, thereby adapting coil 1 to a wider range of wave-lengths than would be possible if the condenser were connected in one fixed way.

A honeycomb coil has the advantage of possessing much lower distributed capacity than single-layer coils, in addition to being a very compact form of inductance. A set using these coils may be readily adapted to all wave-lengths by inserting the proper coils in the "plug-in" mountings. An outfit of this type is characterized by its excellent selectivity, its long distance receptive powers, and its comparative ease of construction.

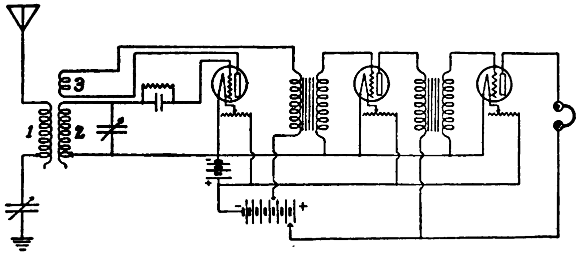


Fig. 1

A number of radio enthusiasts seem to think that the action of a honeycomb-coil set differs from that of other forms of inductors. The circuit in Fig. 1, taken from Chap. 2 (Fig. 16) of the Lefax Radio Handbook, is identical in principle with thefore going honeycomb-coil circuit. The primary and secondary of the coupler, 1 and 2, perform the same duties as coils 1 and 2 in the honeycomb circuit; and tickler coil 3 in Fig. 1 is identical in action with tickler coil 3 in the honeycomb circuit. It should be clearly understood that there is no fundamental difference between a 3-coil honeycomb set and a set using a variocoupler and tickler coil. The only difference lies in the fact that the honeycomb coils are interchangeable, and that instead of securing variation in coupling by means of *rotation*, the honeycomb coils move on hinged mountings through an arc of a circle.

Many experimenters have the idea that circuits using concentrated inductances are different from circuits using single-layer coils. This is not the case. The inductance is the thing we want; how we get it does not matter so much, that is, if we do not introduce other quantities into the circuit by changing the type of coil used. For some purposes some types are better than others, but the fact remains that circuits using concentrated inductances are identical with circuits using single-layer coil inductances. It would be well if experimenters would become accustomed to thinking of inductance in microhenries instead of coils of certain size; then they could easily pick out the size required of any type they wish to use.

The honeycomb-coil circuit shown in Fig. 1 is identical, except for the series-parallel switch and the jacks, to the variocoupler-tickler-coil circuit given in Fig. 16, Chapter 2, of the Lefax Radio Handbook. A reproduction of this circuit is shown in Fig. 2. The coils 1 and 2 are the primary and secondary of a variocoupler corresponding to the primary and secondary honeycomb coils (P and S) in Fig. 1; coil 3 in Fig. 2 is a tickler corresponding to coil T in Fig. 1.

On page 36 is shown the layout for the honeycomb-coil set. In building this outfit, the same general constructional hints given in December Radiofax should be followed. The honeycomb coils are shown mounted in front of the panel, but by means of a special back-panel mounting, which can be procured at most dealers, the coils may be placed behind the panel, with only the two adjusting knobs projecting through to the front.

The wave-length range of this set is approximately 250 to 725 meters, using a 75-turn coil for the primary, a 75-turn for the secondary, and a 50-turn coil for the tickler. The .001 or 43-plate condenser is thrown into the circuit in series to receive the lower wave-lengths up to 500 meters, and is used in shunt for higher values.

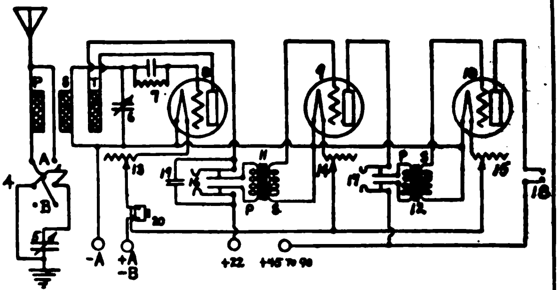
It has been customary in the past, and it is still generally the case, that when a radio experimenter speaks of the inductance required in a circuit, he does so in terms of so many turns of wire in a single layer wound on a core of such and such a diameter. This is his quantitative conception of the magnitude of inductance required, and is a simple and convenient method of visualizing it. However, the difficulty comes when he wants to equip his set with concentrated inductances of any sort, such as bank-wound coils, honeycomb coils, lattice-wound coils, etc. It is not as easy to visualize the magnitude of inductance in coils of these forms. The experimenter generally has no idea at all of what size honeycomb or other type to use in his set.

It is an easy matter, however, to arrive at the size to use by means of the table of inductances of single-layer coils in the September issue of Radiofax, pp. 25 and 26. Let us take an example: Suppose he is building a set which requires a single-layer coil such as described in the Lefax Radio Handbook, Chapter 2, p. 14, the dimensions of which are: diameter of tube, 4 inches; turns of wire, 85; size of wire, No. 18 to 24. In the table referred to, find the inductance of this coil. The diameter of the coil in cms. is $4 \times 2.54 = 10$ cms., approximately. Suppose we use No. 20 D.S.C. wire. The table gives 29.18 turns of wire per inch. The length of the winding will then be $85/29.18 \times 2.54 = 7.5$ cms., approximately. The table shows the value of inductance to lie between 339 and 564 microhenries. Interpolating, the inductance of the coil is found to be 395 microhenries.

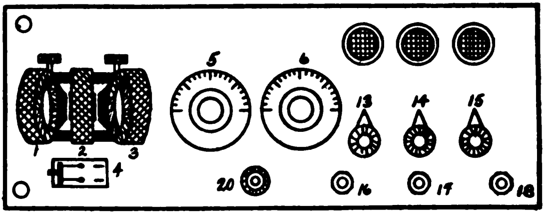
Manufacturers' tables generally give the inductance of honeycomb coils in millihenries—1,000 microhenries equal 1 millihenry. The inductance of the coil in these units is then 0.395 millihenry. By referring to the manufacturers' tables, the size honeycomb coil may be picked out whose value of inductance is nearest to this. In this particular case we would use a 75-turn honeycomb coil. The inductances of all makes of honeycomb coils is not the same. They vary considerably in the larger sizes, although the smaller sizes agree closely enough for ordinary purposes. The same procedure is to be followed in the case of other types of concentrated inductances.

It must be noted here that merely because the circuit requires an 85-turn single-layer coil we do not use an 85-turn honeycomb coil. The relation between the two types of coils is a very complicated one, and must be worked out for each individual case as outlined above. The great advantages of using some of the types other than the single-layer coils are the saving in space and reduction of distributed capacity by winding them in special ways.

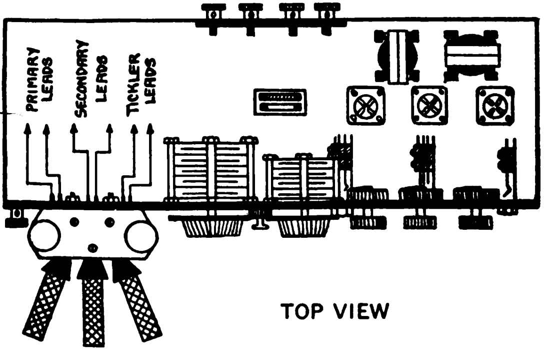
THREE-COIL HONEY COMB SET



CIRCUIT DIAGRAM



PANEL LAY-OUT



TOP VIEW

CHOICE OF A VACUUM TUBE

After designing the antenna, the antenna circuit and the secondary circuit, the next thing to which we must give some thought is the choice of the proper vacuum tube to use. The choice of a tube depends upon the following considerations: (*a*) Whether the tube is to be used as detector, amplifier, or oscillator, (*b*) whether the set is to be portable, self-contained, (*c*) the number of tubes to be used, (*d*) the purpose for which the set is to be used, etc. The last item may be classified under the following heads, viz.: (1) Broadcast listening for the enjoyment of entertainment programs, (2) experimentation on apparatus and circuits, (3) long-distance code reception. We may, in general, make the following classification:

1. Detector.
   (*a*) Soft Tubes.
   Not suitable for portable sets, since all are for operation by storage battery.
   Very sensitive for long-distance reception.
   Rather noisy in operation.
   Require critical adjustment and experienced operator.
   Suitable for long-distance reception and experimental work.
   (*b*) Hard Tubes.
   Quieter and more stable in operation than soft tubes.
   Do not require critical adjustments.
   Different types, suitable for either portable or non-portable sets.
2. Amplifier (all hard tubes).
   (*a*) Radio-frequency.
   Requires low internal capacity.
   (*b*) Audio-frequency.
   Requires high amplification factor.
   (*c*) Power Amplifier.
   Requires low internal output impedance.
3. Oscillator (all hard tubes).
   Same requirements as for power amplifier.

Soft tubes, commonly called gas tubes, are those which have not been evacuated to a very high degree. Their operation is affected by the presence of the gas, and it is due to partial ionization of this gas that extreme sensitivity as a detector may be often secured. They are critical in adjustment with respect to the voltages, and ionize completely on rather low voltages as compared with the hard tubes.

Hard tubes contain very little gas; their operation is thus more stable, and they can be operated at high voltages without ionization, although extreme sensitivity, due to partial ionization, is lacking.

UV-199, C-299, WD-11, WD-12

The UV-199 Radiotron, made by the General Electric Co., is identical in characteristics and construction to the Cunningham C-299. The WD-11 and WD-12 are identical in every respect excepting that the WD-11 requires a special socket. The UV-199 and C-299 also require special sockets. WD-12 fits the standard socket.

The following table gives some of the important quantities to be considered:

	UV-199 and C-299	WD-11 and WD-12
Filament current.....	0.060	0.25
Filament voltage.....	3.0	1.1
Plate voltage supplied by................	2 22½ v. blocks of B-battery	1 22½ v. block of B-battery.

The filament current for all of these tubes may be supplied by No. 6 dry cells. Although the UV-199 requires a larger B-battery than the WD tubes, and also requires three dry cells for filament operation while the WD requires only one, the filament current consumption is less than one-fourth that of the WD tubes, resulting in increased A-battery economy. If two dry cells are used in parallel to operate the WD tubes the life of the cells may be increased as much as 16%. Due to the necessity of using the larger batteries, the UV-199 tube is not as well adaptable for portable or self-contained sets, where weight and size must be reduced to a minimum and where the power output required is relatively small, as the WD tubes. The small electrical capacity between the electrodes of the UV-199 makes this tube adapted to radio-frequency amplification. This tube capacity has been further reduced by a rearrangement of the socket terminals.

All of these tubes operate as detectors or amplifiers, care being taken that proper grid voltages be employed. The values for the grid voltages may be obtained from articles on the individual tubes appearing in Radiofax from month to month.

They are not sensitive to slight variations in plate voltage and tapped batteries are not necessary.

If it is desired to operate small loud speakers, it is particularly important that correct grid and plate voltages be used. For operation of large loud speakers, the UV-201-A or C-301-A are recommended in preference to these small tubes. The larger tubes, on account of their low output impedances, are capable of delivering much larger power outputs than the small ones.

A particular advantage of all these tubes is the elimination of the cumbersome storage battery (and also the chargers).

UV-200 and C-300

These tubes are also identical in characteristics, and are adapted for use by the skilled operator or experimenter interested in code work and reception over long distances. They are not suitable for dry-cell operation as the filament requires one ampere at five volts. The action as detector is very critical in respect to filament voltage and plate voltage. They are sensitive to weak signals, especially spark and modulated CW signals, when skillfully handled by experienced operators in a circuit particularly equipped for the proper voltage operation of filament and plate. They are not adaptable for use in radio or audio-frequency amplification, and require for operation as a detector only one block of B-battery. The tubes require a little patience and skill in adjustment for the reception of weak signals. Under certain conditions they have a tendency to be slightly more noisy in operation than the high vacuum tubes. These tubes fit the standard bases.

These tubes may be operated as amplifiers if a voltage of —1.5 is used on the grid and 25 to 30 volts on the plate. This requires a special C-battery. Use of these tubes as amplifiers is not generally recommended.

UV-201 and C-301

These tubes are interchangeable with the UV-201-A and C-301-A, described below, and may be used in parallel with them, although the filament current consumption of the latter tubes is only one-fourth as great as the former. The UV-201-A or C-301-A are to be recommended in preference to the UV-201 and C-301.

UV-201-A and C-201-A

These tubes are to be used as either detectors or amplifiers. They may also serve as oscillators for small outputs such as are used for heterodyne reception. They are interchangeable with the older UV-201 and C-301 and may be used in parallel with them, although the filament current consumption is only one-fourth as great. They have better amplification characteristics than the UV-201, C-201, UV-199, C-299, and are therefore better suited for the operation of small loud speakers or other purposes requiring somewhat more power than is furnished by the usual type of receiving set equipped with the other tubes. The operation of these tubes is free from variations in results due to slight changes in plate and filament voltages. These tubes are slightly better detectors than the UV-199, C-299, or WD-11.

Notes:

Some of the remarks made above with reference to the various tubes may be somewhat of a surprise to many of our readers. Few have ever heard of the

UV-201-A being used as a detector and that the use of the UV-201 as a detector is not usually recommended by competent authorities. The extreme sensitivity of the UV-200 as a detector is in part due to the presence of a small amount of gas in the tube. It is a "soft" tube; that is, it has not been evacuated to such a degree as the UV-201-A. But this same property which renders it so sensitive as a detector of radio oscillations, at the same time renders it rather unsteady and uncertain in operation. For consistent reception over reasonable distances, then, the UV-201-A is to be preferred to the UV-200; but for experimental work over long distances (so-called DX reception) where consistent and regular communication is not required, the UV-200 may then be used.

The capacity generally used in the grid condenser is 0.00025 microfarad, although the value may be considerably departed from. Values as high as forty times this have been used with good results. The proper size can best be determined by trials, and in some cases it may be advantageous to use a variable type of condenser. A detailed discussion of the grid condenser may be found in the January issue of Radiofax. This article also presents a generalization of the proper connections for the grid return to the filament. It may be well to repeat them here:

For all hard tubes used as detector or amplifier, without grid condenser, connect the grid return to the **negative** side of the "A" battery; for all hard tubes used as detector with grid condenser, connect the grid return to the **positive** side of the "A" battery; for soft tubes with grid condenser, connect the grid return to the **negative** side of the "A" battery.

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

The 2-stage radio-frequency amplifier diagrammed on the following page is adapted for use with practically any standard receiver. If a vario-coupler is used in the set, the secondary leads should be broken, and then run to the terminals marked input on the circuit in diagram 1. Then connect the grid and—A leads of the set to the corresponding terminals shown in diagram 1. Make the other connections as indicated. If it is desirable to use a loop antenna, connect the ends of the loop to the input terminals of the R. F amplifier, disconnect the coupler from the set, and connect grid and —A terminals of the amplifier direct to the grid and —A terminals of the detector tube.

The parts required for the R. F. amplifier are: (1) One 23-plate (.0005) variable condenser; (2) a 200- or 300-ohm potentiometer; (3-4) two 6-10 ohm rheostats (30-ohm rheostats with UV-199's); (5-6) two R. F. transformers; (7-8) two amplifier tubes and two tube sockets; 1 dial, 6 binding posts, and a 6"x10" panel.

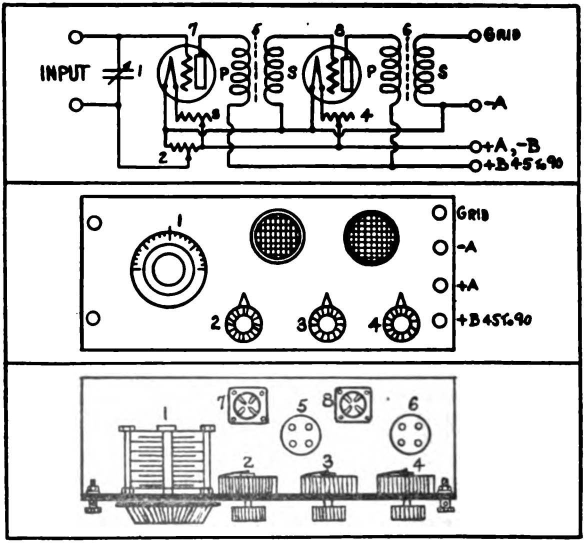
The 2-stage audio-frequency amplifier is readily attached to any set by connecting the input terminals in place of the phones on the set in question. The other connections are indicated on the other terminals.

The parts required for the A. F. amplifier are: (1-2) Two A. F. transformers; (3-4) two amplifier tubes and two tube sockets; (5-6) two 6-10 ohm rheostats; (7) one double-circuit jack; (8) one single-circuit jack; (9) one .001 condenser; 5 binding posts; a 6"x10" panel.

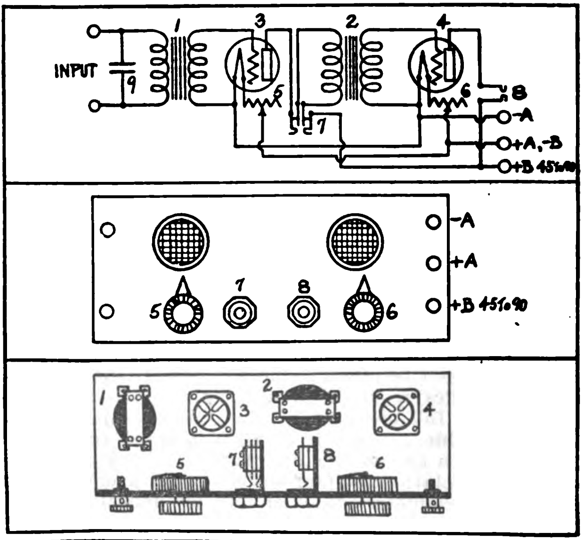
The radio-frequency amplifier may be attached to any receiver, regenerative or otherwise, without altering the set itself as follows: Connect a loop antenna to the input terminals of the amplifier; connect the grid terminal of the amplifier to the antenna binding post of the set, and connect the —A terminal of the amplifier to the ground binding post of the set. See that the ground binding post is connected directly to the negative side of the A battery in the set. Of course, the antenna and ground leads are removed from the set itself, the loop antenna replacing these at the input to the R. F. amplifier. If an outdoor antenna is desired instead of the loop, change the variable condenser from its shunt position and place it in series with the antenna, which should be connected to the upper input terminal of the R. F. amplifier. Shunt an ordinary single slide tuner across the input terminals and connect the lower input terminal to the ground. This arrangement provides a single-circuit tuning control which delivers the full energy of the outdoor antenna into the R. F. amplifier, which is in turn coupled to the set itself through the latter's own tuner. Using regeneration in the plate circuit of the detector, accomplished either by variometer or tickler coil, compensates for the resistance of the direct coupled antenna system.

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

1.—TWO-STAGE R. F. AMPLIFIER



2.—TWO-STAGE A. F. AMPLIFIER



THE 4-TUBE SUPERDYNE RECEIVER

The superdyne circuit is characterized by its good selectivity, its long range ability, and its excellent signal volume for loud-speaker work. Either an outdoor or indoor antenna may be used, the former being connected as shown in the diagram, and the latter being connected to the point where condenser 7 joins the grid lead of the R. F. amplifier. Coil 1 is then cut out of circuit. The parts required to build this receiver are:

(1) Primary coil, made by winding 4 turns of No. 22 double silk-covered wire over the secondary, coil 2. Connect the ends to binding posts on the tube.

(2) Secondary coil, made by winding 42 turns of No. 22 D. S. C. wire on tube 4" in diameter. Take off a tap at the 20th turn, and connect to a binding post on the tube. Connect the two outer ends of the coil to two other binding posts on the tube. The binding post arrangement greatly facilitates wiring up the set.

(3) Tickler coil, made by winding 18 turns of No. 22 D. S. C. wire on each side of a rotor 3⅝ inches in diameter. (Total, 36 turns.) Make pig-tailed connections from the rotor coil to two binding posts conveniently mounted on the stator tube.

(4) Radio-frequency coil, made by winding 46 turns of No. 22 D. S. C. wire on a tube 4 inches in diameter. Take off a tap at the 25th turn, and connect to a binding post on the tube. Likewise, connect the outer ends of the coil to binding posts.

(5)–(6) Switch knobs and contact arms for making connection to either center taps or ends of coils 2 and 4. The center taps are used for wave-lengths below 300 meters, and the end taps are used for broadcasting programs on wave-lengths up to 660 meters.

(7)–(8) Two 23-plate variable condensers (.0005 mfd.).

(9)–(10)–11)–(12) Four 6-10-ohm rheostats.

(13) One .001 mfd. fixed condenser.

(14) One .00025 mfd. fixed condenser.

(15)–(16) Two double-circuit jacks.

(17) One single-circuit jack.

(18) One W-201A as an R. F. amplifier.

(19) One UV-200, for detection.

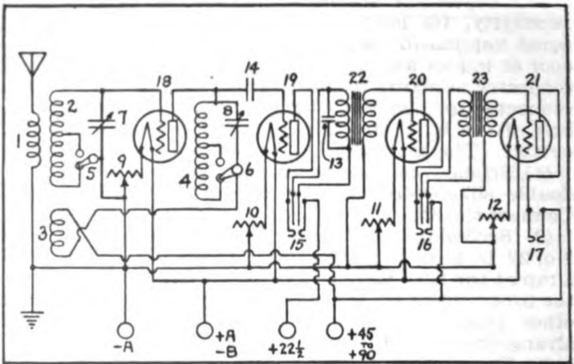
(20)–(21) Two UV-201A's for A. F. amplification.

(22)–(23) Two A. F. transformers.

Other necessary equipment comprises four standard tube sockets, three 3-inch dials, 6 binding posts, and a 6 in. x 24 in. panel.

Although the use of the detector by itself is said to be unsatisfactory, we have inserted a jack here because some experiments made on home-built receivers have given good results on the detector jack.

The tickler coil in the superdyne receiver has its connections reversed. This results in a negative feed-back which prevents oscillation of the tubes and enables them to be operated with the circuits at resonance.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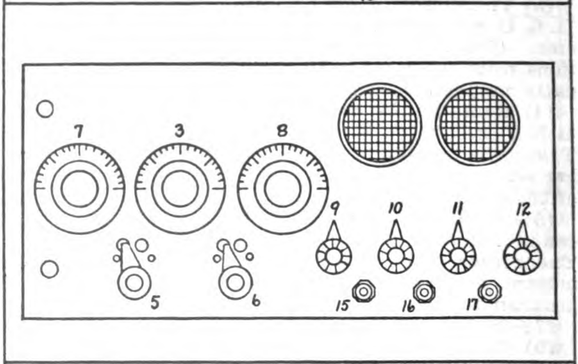
23
-A
+A
-B
+22½
+45
TO
+90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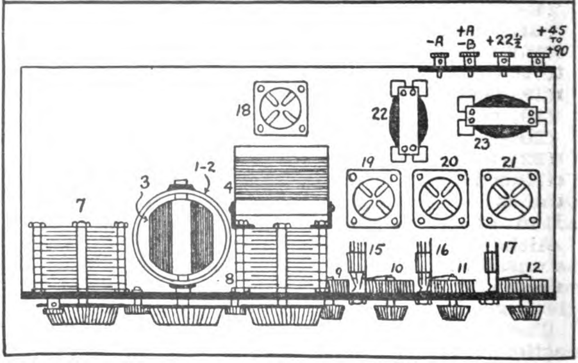
-A
+A
-B
+22½
+45
TO
+90
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CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

Push-Pull Amplifier

The amplifier diagrammed here may be added to a detector outfit or a set using one stage of audio-frequency, as shown in the accompanying sketches. Five ordinary audio-frequency transformers are used in place of the special push-pull transformers. The parts required to construct this amplifier are:

1.—Single circuit jack, used for connection to receiving set.

2.—Single circuit jack, used for output to loud speaker.

3.—Any well-constructed A. F. transformer, about 3½ to 1 ratio.

4–5–6–7.—Four well-constructed A. F. transformers of uniform design. Transformers 4 and 5 are coupled together as shown and form a push-pull "input" transformer. Transformers 6 and 7 are coupled together and form a push-pull "output" transformer. It is important that the transformers comprising each pair have as nearly the same electrical constants as possible. If the special "5-terminal" push-pull transformers are used, the input transformer replaces 4 and 5, and the output replaces 6 and 7, and in this case transformer 8 is not needed.

8.—A fifth A. F. transformer of the same design as the other four, and used to couple the push-pull amplifier to a loud speaker. It will be noted that transformer 8 is used in the reversed position, i. e., used as a step-down transformer, in order to match the impedance of the amplifier to that of the loud speaker.

9–10.—6 to 10 ohm rheostats.

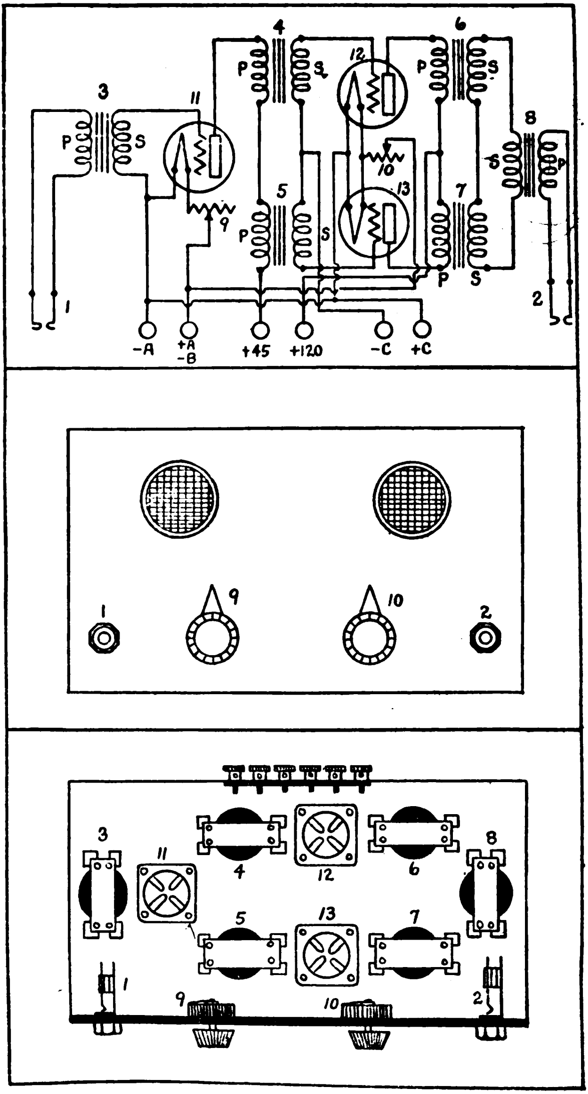
11–12–13.—Three amplifier tubes and three sockets. UV-201 A's may be used, but a preferable arrangement is to use a UV-201A at 11, and two 216A's or VT-2's (203B) at 12 and 13.

If a phone condenser is not already incorporated in the detector circuit of the receiving set it may be well to connect a 0.001μf. fixed condenser across the terminals of jack 1. This is to be done in accordance with the remarks on page 2 of the February issue.

If the amplifier given here be added to a detector unit, the combination will consist of detector, one stage of ordinary audio-frequency (included in following diagrams), and one stage of push-pull amplification. If added to a set consisting of detector and one stage of A. F., the combination will comprise two stages of ordinary A. F. and a push-pull stage. If the amplifier described here be added to a set already employing 2 stages of A. F., distortion may result, due to excessive A. F. amplification. It should be remembered that a stage of push-pull amplification does not remove distortion of previous stages, but simply amplifies, without further distortion, the signal voltages passed into it.

CONTRUCTIONAL HINTS ON POPULAR CIRCUITS

Push-Pull Amplifier



CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

The circuit diagrammed on the following page involves one stage of untuned R. F., one stage of tuned R. F., regenerative or non-regenerative detector, and two stages of A. F. amplification. A variometer is employed as inductance in the antenna-ground circuit, and another is used, if so desired, for regeneration in the plate circuit of the detector tube. The figure 8 designates the position of the second variometer, when regeneration is desired. This instrument is not shown in the panel layout and interior arrangement, for sake of simplicity. It may be mounted to the right of condenser 4 by moving the jacks and rheostats closer together. The parts required to construct this set are:

(1)-(4).—Two .0005 mfd. (23-plate) variable condensers.

(2)-(8).—One or two standard, well-made variometers.

(3).—One 200-300 ohm potentiometer.

(5).—Coil made by winding 85 turns of No. 22 D.S.C. or D.C.C. wire on a 4-inch diameter tube.

(6).—One .00025 mfd. grid condenser.

(7).—One grid leak of about ½ to 2 megohms. A variable leak of ½ to 10 megohms would no doubt prove most satisfactory.

(9)-(10)-(11)-(12)-(13).—Five 6-10 ohm rheostats. If so desired, the two R. F. amplifiers may be controlled by one rheostat, as also may the two A. F. amplifiers.

(14).—One well-made radio-frequency transformer, range 200 to 550 or 600 meters.

(15)-(16).—Two good audio-frequency transformers.

(17)-(18).—Two double-circuit jacks.

(19).—One single-circuit jack.

(20)-(21)-(23)-(24).—Four UV-201A amplifier tubes.

(22).—One UV-200 detector tube.

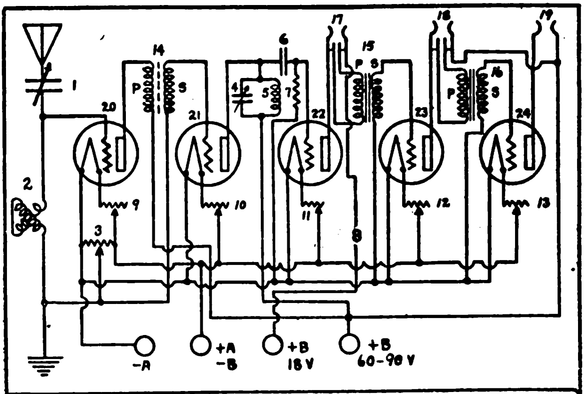
The panel should be 6" to 8" high and 21" to 24" long.

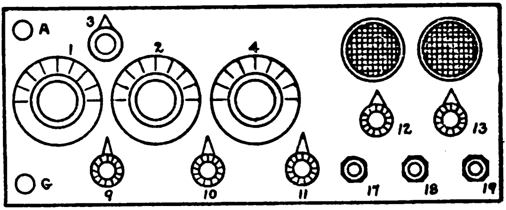
Five tube sockets, four binding posts, three dials, 6-volt storage battery, and four 22½-volt B batteries will be required to complete the outfit.

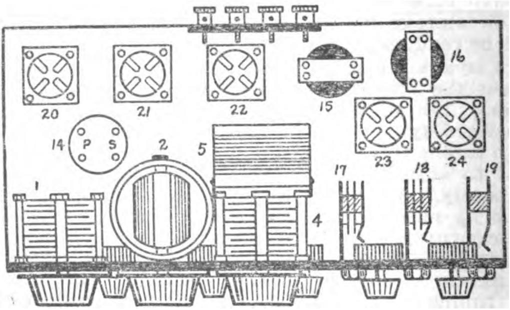
It is advisable to try a .001 mfd. fixed condenser across the primary terminals of the first A. F. transformer. In some instances this will improve results considerably.

In tuning this circuit to a desired station it is important to adjust both circuits (1)-(2) and (4)-(5) simultaneously. The final tuning may be conveniently done by means of the variable condensers. Then, in the case of the regenerative set, by adjusting the plate variometer (8) the signals can be brought up to the maximum strength. In some instances this changes the tuning of circuit (4)-(5), in which case a final readjustment of this circuit is advisable.

TUNED RADIO-FREQUENCY CIRCUIT
WITH OR WITHOUT REGENERATION







CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

The Teledyne Receiver

The Teledyne circuit consists of a tuned radio-frequency amplifier, partially regenerative; detector, and two stages of audio-frequency amplification. It is characterized by its sensitivity, selectivity, comparative ease of tuning, tone quality, and absence of over-regeneration in the antenna circuit. This latter characteristic prevents re-radiation, avoiding annoying squeals and howls in neighboring sets. A single-wire antenna with a total length of 60 to 100 ft. is most satisfactory. For long-range reception an antenna up to 150 ft. in length may be employed.

Apparatus Required

In constructing this circuit, the following list of materials should be followed as closely as possible, and it is important to use high-grade equipment throughout.

(1)—Variable condenser, .00025 mfd.

(2)—Primary coil of 105 turns, No. 26 D.S.C. wire.

(3)—"Plate delivery" secondary coil of 4 turns, same size wire.

(4)—"Detector grid" secondary coil of 45 turns, same size wire.

(5)—Regeneration coil of 9 turns, same size wire.

(6)—1 megohm grid leak.

(7)—Dubilier grid condenser, .0005 mfd.

(8)—.0003 mfd. variable condenser with 3-plate vernier (9).

(10)—.1 mfd. Dubilier by-pass condenser.

(11)—.002 mfd. Dubilier phone condenser, type 601T.

(12)—20-ohm rheostat.

(13)-(14)—30-ohm rheostats.

(15)-(16)—Audio-frequency transformers, ratio 5:1. (High impedance.)

(17)—Single-circuit jack.

(18)-(19)-(20)-(21)—Four UV-199 tubes and sockets. Socket (18) may be of the plain type, but (19), (20), and (21) should be of the shock absorption type.

The balance of the equipment needed is: Switch contact arm and two contact points; 8 binding posts; mounting brackets for coils; necessary dials; panel approximately 8 by 18 inches; shield plate or aluminum foil slightly smaller than panel or at least large enough to cover the condensers and coils; one spool No. 26 D.S.C. wire (¼ lb.).

Coil requirements: One Bakelite tube 2⅞" outside diameter, 1/16" wall, 3½" long (primary coil tube); one Bakelite tube 4" outside diameter, 1/16" wall, 2⅛" long (secondary coil tube); one Bakelite tube 3¼" outside diameter, 1/16" wall, ¾" long (regeneration coil tube).

The batteries necessary to operate this set are three 1½-volt dry cells connected in series (A battery); four 22½-volt B batteries, and one 4½-volt C battery.

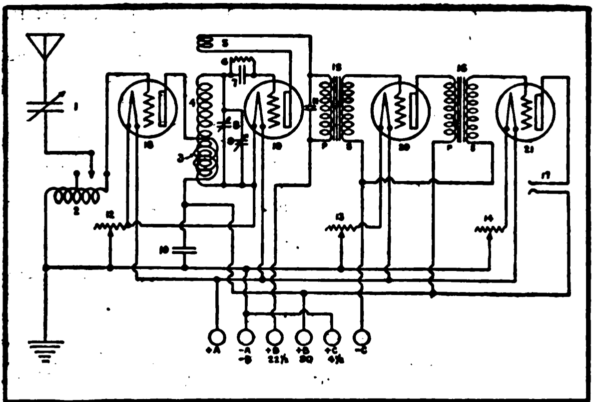
Primary Coil

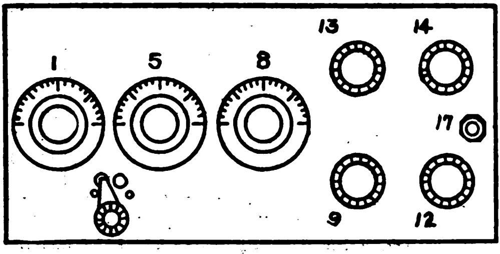
The most important thing in assembling the Teledyne circuit is the winding of the coils. Painstaking care must be given to this. For the primary coil (2), wind 105 turns of the No. 26 wire on the above specified tube. The windings will cover 2⅞" of the length of the tube, and should be centrally located. Drill small holes to anchor the beginning and end of the wire. Starting at the left end of the coil, anchor the starting end of the wire in two small holes drilled about ½" apart on the same circumference of the tube; then, holding the side of the tube towards you, and keeping the wire taut, rotate the tube in a clockwise direction with the right hand, and guide the wire onto the tube so that it wraps on from left to right. Wind on 65 turns in this manner, loop the wire, and take off a tap, leaving about 6" for connecting to the switch point. Continue winding in the same direction until 40 more turns are wound on. Anchor this end as before, leaving about 6" for connecting. A dilute solution of collodion, procurable at a drug store, may then be used to coat the wiring so that there will be no possibility of the wire coming loose or sliding off the coil.

Secondary Coils

The Teledyne secondary consists of two windings, (3) and (4), the former comprising 4 turns of the No. 26 wire wound directly over the detector grid coil, or secondary, of 45 turns, same size wire. The 4-turn coil is the plate delivery coil of the radio-frequency tube, and is especially critical, requiring unusual care in winding. Separating these two coils is a thin piece of Bakelite or impregnated cardboard. It is well to impregnate the cardboard, if used, with a dilute solution of collodion. This prevents absorption of moisture and assures better operating conditions. The strip should not be more than 1/32" thick and about ⅜" wide. A strip 12¾" long will just go around the secondary coil over the lower winding. In winding the secondary, start at the left, about ¼" from the end of the tube, and wind in the same direction as in the case of the primary coil, putting on 45 turns of wire, closely wound. Anchor as before, leaving several inches for connecting. The winding when completed will leave space on the tube, at the right-hand end, for drilling the two holes for the shaft of the regeneration coil. These holes, located ¼" from end of tube, must be very accurately drilled, otherwise the dial will probably wobble when attached to the shaft.

After winding the lower coil, or secondary, coat it with collodion as in the case of the primary. Fasten


+A
-A -B
+B 22½
+B 90
+C 4½
-C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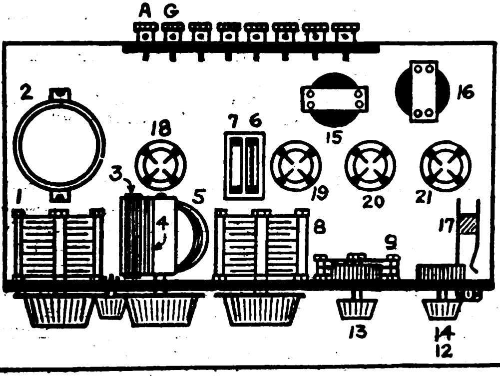
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the insulating strip around the left end of these windings, using a rubber band or drop of glue to hold it in place. Now, the plate delivery coil of 4 turns is wound on top of this insulating strip in the same direction as the other coil, and very carefully placed so that the first turn of the upper coil is over the first turn of the lower. This is very important. To aid in holding the wire, small pieces of cloth tape must be folded and inserted under the windings, the ends of the coil slipped through the projecting loops of the tape and pulled tight. The coil is then coated with collodion as before and allowed to dry.

Regeneration Coil

The regeneration coil is wound on the ¾" long Bakelite tube specified above. Start the windings to the extreme left. Two holes are accurately drilled through the center of the tube for the shaft. The same size wire is used in winding this coil, the direction of winding being opposite to that of the other three coils. This coil consists of 9 turns. When finished it should be coated with collodion. The ends of this tickler coil should be securely anchored and soldered to flexible leads to facilitate connections.

With the aid of suitable bolts and shaft, mount the regeneration coil within the right-hand end of the secondary tube so that the windings on the regeneration coil are on the inside. If this is carefully followed, and all the winding directions are as described above, the rear connection of the tickler will go to the plate of the detector tube, while the other connection will go to the outside winding of the A. F. transformer primary and thence to the detector "B" battery. The experimenter will undoubtedly have many ideas as to the assembling of regeneration and secondary coils, so that part will be left entirely to the builder's discretion. Suitable mounting brackets may readily be fastened to the left end of the secondary tube. All that must be remembered is that the regeneration coil must be swung inside the secondary coil at the end opposite to the one carrying the 4-turn plate delivery coil of the radio-frequency tube. The assembly of this complete unit will depend upon the particular style of panel layout used.

Panel Layout

While the assembly and panel layout of the Teledyne will depend upon the particular kind of apparatus used, still there are certain fundamental principles to be rigidly observed in carrying out this construction. A general idea of arrangement is gained by studying over the lower sketch in the accompanying constructional layout. The manufactured set is shown on page 46 of April Radiofax. The primary coil may be mounted directly on the back of the primary condenser. This coil should be placed exactly vertical. To the right of

this is shown the secondary and regeneration coils, arranged close to the panel. Another satisfactory arrangement which will insure even less inductive coupling between coil 2 and the regeneration unit is to move the entire unit, consisting of coils (3), (4), and (5), back so that a horizontal line drawn through the center of coil (2) will pass through the axis of coils (3) and (4); a long shaft for the regeneration coil will be required in this case. This arrangement is completed by placing tube socket (18) close to the panel, to the right of condenser (1). This method of layout insures the shortest possible connections.

Secondary condenser (8) is shunted by vernier condenser (9). The vernier shown in this case is separate and actuated by a separate control to the right of the main control. This is not essential, however, as any type of vernier condenser rated at .0003 mfd. is suitable.

In the rear on a shock-absorbed mount or platform are mounted the grid condenser and leak, to the left, while the detector and two A. F. amplifier tubes are to the right. In the factory-made set a special switching condenser used in place of the ordinary primary condenser makes the use of a switch lever and points unnecessary. These condensers are not procurable on the market, so the switch lever and points must be used.

It may be well to use a baseboard to which the front panel can be mounted so as to allow the units to be arranged more conveniently. For instance, the primary coil can be mounted directly on the primary condenser, with the R. F. tube socket placed on the base alongside of it, making short leads possible. The secondary regeneration coil assembly may then be mounted next to this, to the baseboard, as suggested in the second method of arrangement for this unit. If the long shaft necessary to accomplish this arrangement is obtainable, it is advisable to move this entire unit back until it lines up with the primary coil, as explained before. This will place the coils exactly in line both ways, but at right angles to each other.

Care should be taken when arranging the apparatus to see that all connecting wires will be as short as possible and at the same time not come too close to one another. This applies especially to the radio-frequency leads. When the binding posts and other odds and ends are assembled, the set is ready for wiring, as shown in the accompanying diagram. The set may be made entirely self-contained by using a cabinet deep enough to hold the dry A, B, and C batteries.

Theory of Operation

The Teledyne circuit employs regeneration and radio frequency in such a manner as to eliminate re-radiation. The principle of regeneration is used in a great number of broadcast receivers now in use. This feature of regeneration may turn the set into a small transmitting

unit if operated at the oscillation point, and produces the phenomenon of re-radiation. Therefore, unless properly operated, a set of this type can interfere severely with the results of receiving sets within a radius of a block or two.

In the Teledyne circuit the beneficial effects of regeneration are retained, such as increased volume, range, and selectivity, but at the same time so employed that oscillations are prevented from getting into the antenna circuit. The first stage of the Teledyne circuit operates in the following manner: It is well known that when a resonant circuit, consisting of an inductance and a capacity in parallel, is placed in series with the plate circuit of a vacuum tube whose grid circuit is also resonated to the same frequency, the resonant plate circuit will produce oscillations, and, somewhat off this resonant point, "negative resistance," or regeneration. If this circuit is coupled with the plate circuit with sufficiently close coupling, the same phenomena will occur. If, however, the coupling is at a certain critical value, regeneration can be produced without possibility of oscillation. This latter value is used in the Teledyne.

The plate circuit of the first stage is coupled, at the critical value mentioned heretofore, to the grid inductance of the detector, which latter is tuned by the usual variable condenser. The adjustment of this condenser resonates the detector grid circuit and at the same time regenerates the R. F. amplifier, thereby increasing its response by lowering the antenna resistance.

The antenna inductance, which is also the grid inductance of the radio-frequency amplifier, is mounted at minimum coupling position with the detector grid inductance. This is necessary in order to prevent parasitic feedback causing oscillation of the first tube.

There are two methods of tuning the Teledyne set: First, the regeneration of the detector may be left low and the antenna condenser and detector grid circuit tuning condenser may be handled in a manner resembling the tuning of a one-stage neutrodyne. The second method is similar to the usual manner of handling a two-circuit regenerative receiver, i.e., oscillate the detector, turn its condenser until a heterodyne note is heard, tune the antenna until the note is loudest, and then reduce the regeneration. The difference is that the heterodyne note does not go out on the air and become annoying for several blocks in all directions.

The Teledyne receiver has been especially designed for use with UV-199 tubes, and in this form it is readily adaptable for portable use. An attempt to employ other types of tubes would undoubtedly necessitate an entire rebalancing of the circuit as far as its electrical constants are concerned, in order to obtain maximum performance.

CONSTRUCTIONAL HINTS ON POPULAR CIRCUITS

The 2-Tube Harkness Reflex Set

This receiver is so designed as to be non-oscillating and to function at high selectivity and high audibility, while, in addition to this, possessing the features of being inexpensive, easy to build, and simple to operate.

The parts necessary to construct this set, numbered on the circuit diagram, are as follows:

(1)–(4).—Two Harkness coils, which can either be purchased or constructed as described below.

(2)–(5).—Two standard, well-made 23-plate (.0005 mfd.) variable condensers.

(3)–(6).—Two well-made audio-frequency transformers.

(7).—One .0006 mfd. fixed condenser, preferably of the mica type.

(8).—One 6-ohm rheostat.

(9).—One well-made and sensitive fixed crystal detector.

(10).—One single-circuit filament-control jack.

(11)–(12).—Two UV-201A amplifier tubes, with sockets.

Miscellaneous: 7" x 10" panel; 5 binding posts; two dials; suitable brackets to mount coils to condensers; baseboard 10" x 10"; two 45-volt "B" batteries, or four 22½-volt batteries; 6-volt storage "A" battery.

It will be noted that this circuit consists of one stage of tuned radio-frequency, crystal detector, and two stages of audio-frequency amplification. The successful operation of the set depends to a great extent upon the design and careful construction of the coils 1 and 4. If these are not designed correctly, the receiver will either give poor amplification or will oscillate. It must be remembered that the capacity variation and resistance of the variable condensers used in the circuit affect, to a considerable extent, the number of windings required in constructing the coils.

Construction and Assembly

Radio-frequency coil 1 is made by winding the secondary of 60 turns of No. 28 double silk-covered wire on a bakelite tube 2⅝ inches in diameter and 2 inches long. The primary winding of 20 turns, same size wire, is wound directly over the secondary, the two windings being separated by a piece of heavy insulating paper or cloth. Coil 4 consists of a secondary of 60 turns over which is wound a primary of 32 turns, using the same kind of wire and same size tube as in the case of coil 1. These figures are based on the use of the average make of .0005 mfd. variable condensers. It might be well for the builder to try an experimental set of these coils, using 60 turns on the secondary and 15 turns on the primaries.

When the coils are completed, it is a good plan to coat them lightly with a thin solution of collodion and allow them to dry thoroughly. This will hold the windings in place and eliminate moisture absorption.

If it is desired to make the set more compact, the tube sockets may be mounted on a platform under which may be placed the two audio-frequency transformers. The filament-control jack simplifies the operation of the receiver considerably, as does also the fixed crystal detector. Inasmuch as both tubes used are amplifiers, a "B" battery voltage of 90 is used on the plates.

The various units should be arranged as shown in the constructional layout, unless the platform idea for the tube sockets and transformers is followed. In wiring up the circuit, use as short pieces of wire as possible, and it is best to solder all connections.

This circuit can be converted into the single-tube Harkness receiver by removing tube 12 and making the following changes in wiring:

Remove A. F. transformer 6, condenser 7, and jack 10. This, of course, eliminates the wires running to jack 10 and tube 12. Break the line connecting the two negative filament terminals of the tubes (upper filament lead in diagram), and place rheostat 8 below tube 11 in the diagram, connecting the resistance wire of the rheostat to the right-hand filament terminal of tube 11 (negative) and running the arrow-point lead down to the negative side of the "A" battery. The wire from —A to the jack may then be removed, as may also the short wire from +B to the jack. Of course, all wires that had been connected to the secondary of the discarded A. F. transformer may be removed.

The last step, then, is to insert the phones or a single-circuit (not filament-control) jack across the points formerly connected to the primary of the A. F. transformer. The single-tube set thus involves one stage of R. F., crystal detector, and one stage of A. F.

Theory of Operation

In the ordinary reflex circuit, the tendency toward self-oscillation is so great that it is necessary to use a potentiometer or some other agency to impress a positive charge on the grid in order to suppress self-oscillation. Inasmuch as the R. F. amplifier tube is also used for A. F. amplification, it is impossible to use a potentiometer to secure the stabilizing positive bias on the grid for the R. F. amplifier without simultaneously making the grid positive for A. F. amplification; and A. F. amplification will be practically zero unless the grid be operated at a *negative* potential.

It would be possible to balance the self-oscillations by employing capacitative or reversed inductive feedback. But these methods have certain objectionable

features when used in a circuit having a variable resistance unit, such as a crystal detector, and the adjustment would be unstable.

An entirely different system is used in the Harkness circuit to prevent self-oscillation. If the grid and plate circuits of a vacuum tube are adjusted to the same frequency, the capacity between the tube elements is large enough to feed back the energy necessary to produce self-oscillation. Now, if a separate circuit is closely coupled to either plate or grid circuit, it will bring about, when tuned, a decrease in local oscillations, and this reduction will prevent self-oscillation if the initial amplitude of the local oscillations is not too great. In addition to this, the energy in the separate or independent circuit may be delivered to a rectifying agent, as a crystal detector, whose damping effect will assist in the prevention of self-oscillation. It will be noted from the circuit diagram and constructional data that the primary coil of transformer 4 is in close inductive relation to the tuned secondary circuit, the latter functioning as the independent third circuit, and, incidentally, as the tuned input to the detector.

Operating the Receiver

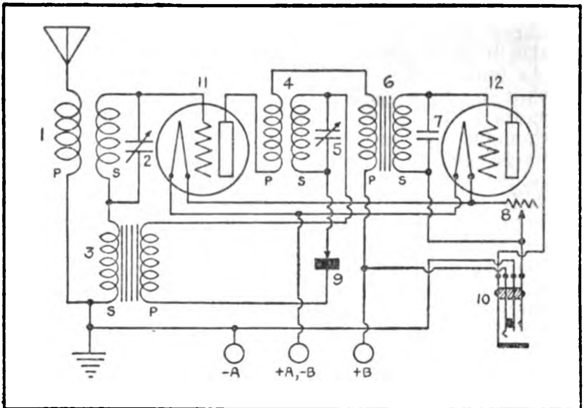
For most satisfactory results on this set, a single-wire antenna of 100 to 150 feet, located 25 to 30 feet above the ground, should be used. However, a shorter antenna may be employed with good results. As a rule, the set can be effectively operated with the ground connection alone, the results equalling if not surpassing those obtained by the use of a short antenna. In this case, the ground wire is connected to the antenna binding post on the set.

To operate the set, turn on the rheostat and insert the phone plug in the jack, whereupon the tubes should light at once if the circuit is properly wired. Both dials are then turned to the same position and slowly varied, keeping them approximately in the same relative positions. Upon hearing a station, rotate the grid condenser until the signal becomes stronger.

Both dials should almost coincide for any wavelength, using the average antenna. If an adjustable crystal detector is used, loud clicks will be heard (as the crystal is adjusted) when the detector and grid circuits are in tune with each other. The clicks are loudest when these circuits are in exact resonance.

Both controls are extremely critical on weak signals. On strong signals, the condenser in the detector circuit is not very critical, but unless carefully tuned, the peak of resonance may be passed over and the station lost. Therefore, do not vary this control too rapidly.

If the set is constructed according to the above specifications and instructions, it is possible to tune in stations repeatedly on the same dial settings as used previously. Hence, a radio log is a valuable asset to the operator.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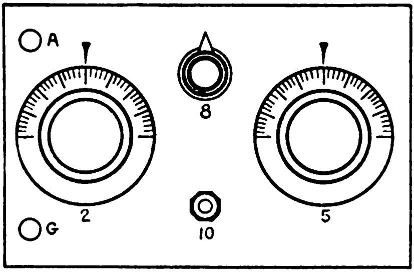
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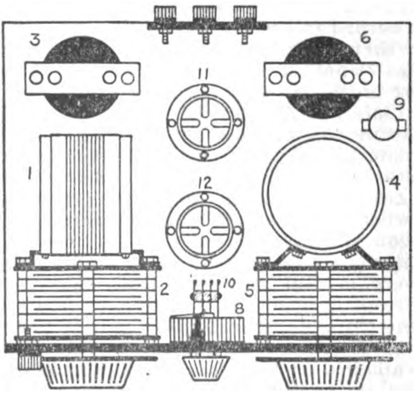
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TABLE OF CONDENSER CAPACITIES

(See Editorial and page 34)

Manufacturer	Type	No. of plates	No. of plates in Vernier	Capacity (micro-microfarads) 0	25	50	75	100	Notes
Acme Apparatus Co.		29		19	88	213	348	478	3
Aerovox Wireless Corp.	.00025	Fixed						256	
"	.0005	"						487	
"	.001	"						999	
"	.002	"						1842	
"	.006	"						6020	
Amplex Instrument Lab.				76				392	1a
" (Grid-Denser)				279				978	1a
Amsco Products Co., Inc		13		14	48	98	143	194	
"		23		13	86	179	280	377	
"		23	3	13	87	182	276	367	
				49	126	224	316	406	
"		43		17	166	347	529	691	
"		43	3	17	168	354	544	722	
				46	196	387	574	756	
Atwater Kent Mfg. Co.	4270	19		22	79	172	262	347	2
"		16		16	66	143	217	282	2
Bruno Radio Corp.		11		14	70	136	197	268	11
				17	131	267	397	520	11
Buell Mfg. Co. (Flewelling Type)	R	23		9	113	237	362	490	
Caldbeck Tool & Mfg.Co.	(Demcal)	23		12	42	117	227	353	6
Cardwell Mfg. Corp	141B	11		13	66	129	190	250	
"	152B	17		16	97	195	286	374	
"	123B	21		17	125	242	366	476	
"	137B	41		24	246	489	728	961	
Carter Radio Co.	.01	Fixed							
"	.04	"							
Chelten Electric Co.	820	11		34	87	141	194	253	
"	815	17		34	113	205	309	388	
"	810	23		43	151	272	400	517	
"	800	23	9	55	157	291	422	556	
				60	175	304	432	559	
"	805	45		41	264	526	774	1017	
"	790	45	9	60	261	513	772	1031	
				71	278	527	783	1043	
Connecticut Tel. & Elec. Co. (Triple-Range)	D-10	3	G-AB	120	200	315	515	850	5
			G-A	90	140	210	355	565	5
			G-B	63	93	125	180	320	5
Crosley Mfg. Co.		2		37	40	227	503	554	8
							570	747	8
Dayton Fan & Motor Co. (Day-Fan)	5017	23	1	27	136	261	322	495	
				34	140	264	386	501	
De Forest	CV-600	25	1	29	152	305	440	554	
				34	159	312	447	560	
"	CV-1503	31	2	31	157	458	780	1111	
				32	163	469	797	1133	
"	CV-1003	45	2	33	227	701	1177	1563	
				41	236	707	1186	1575	
Dubilier Condenser & Radio Corp (Type 601)	.0001	Fixed						102	
	.00025	"						288	
	.0003	"						300	
"	.0005	"						480	
"	.001	"						858	
"	.0015	"						1900	
"	.003	"						3095	
"	.004	"						4100	
"	.005	"						5020	
"	.006	"						6240	
"	.0075	"						7430	
Duplex Engine Gov. Co.	DR-23	23		21	137	269	407	534	
Eisemann Magneto Corp	LBV	14	1	38	155	303	445	570	
				65	183	333	476	599	
Electrical Research Lab.	.0001	Fixed						81	

Manufacturer	Type	No. of plates	No. of plates in Vernier	Capacity (micro-microfarads) 0	25	50	75	100	Notes
Elec. Research Lab. (Erla)	.00015	fixed						125	
"	.00025	"						250	
"	.00035	"						310	
"	.0005	"						500	
"	.0008	"						750	
"	.001	"						999	
"	.002	"						2010	
"	.005	"						4900	
"	.006	"						6000	
Elgin Tool Works, Inc.		3		4	15	23	34	41	
"		11	2	10	53	104	154	201	
				24	66	117	166	216	
"		17		12	82	161	242	316	
"		23	2	19	117	224	335	437	
				31	131	239	349	449	
"		43	2	25	219	425	639	837	
				39	234	442	654	849	
Fada, (F. A. D. Andrea,		13		8	79	161	242	319	
Inc.)		23		11	127	254	380	498	
Federal Tel. & Tel. Co.	45	11		16	67	139	211	276	
"	82	11		37	69	134	202	265	2
"	46	21		21	122	258	391	514	
"	83	21		17	124	252	386	513	2
"	47	43		22	121	516	792	1054	
"	85	43		31	261	540	834	1105	2
Framingham Co.	10	14		23	66	126	184	244	
"	11	14	3	24	69	127	187	254	
				63	107	166	231	292	
"	12	26	3	27	124	255	386	508	
				66	157	291	422	542	
"	14	50		36	217	465	716	956	
"	15	50	3	40	222	468	721	967	
				85	267	514	768	1011	
Freed-Eisemann Corp.	358	13		12	76	161	242	288	10
Freshman Co., Inc	.0003			26	97	182	269	330	12
Gardiner & Hepburn	13	13		14	81	146	209	262	7
(Continental Lo-Loss)	18	18		19	79	184	269	347	7
"	25	25		18	122	296	352	500	7
	45	45		34	202	474	762	1102	7
General Instrument Corp	46A	13		11	82	156	230	307	10
"	46D	21		13	111	344	370	499	10
"	46F	43		20	231	498	767	1029	10
General Radio Co.	247H	26	Gear	21	119	266	389	506	
"	239G	33	"	19	138	436	748	1047	
Gilfillan Bros., Inc.	R-425	11		14	53	91	143	199	
"	R-400	17		19	61	131	119	317	
"	R-375	23		19	76	175	294	404	
"	R-750	23	3	19	76	169	371	386	
				46	116	206	307	422	
"	R-350	43		23	137	310	523	737	
"	R-725	43	3	22	176	402	585	827	
				67	208	496	621	862	
Hammarlund Mfg. Co.	.00025	11		18	65	121	181	221	4
"	.00038	17		18	99	195	291	383	4
"	.0005	23		20	135	262	385	501	4
"	.001	43		25	249	499	753	984	4
Hartford Instrument Co	23SP	23		18	114	224	331	431	
" (Sexton)	23SD	21	3	16	101	200	304	299	
				51	136	234	338	432	
Horne Elec. & Mfg. Co.	355	18	3	6	29	142	270	396	
				57	80	237	322	447	
Kellogg Switchboard & Supply Co.	601	11	3	24	56	113	197	377	
				94	130	184	272	454	
"	603	23	3	24	89	217	433	717	
				97	161	288	502	884	

Manufacturer	Type	No. of plates	No. of plates in Vernier	Capacity (micro-microfarads) 0	25	50	75	100	Notes
Kellogg Switchboard & Supply Co.	605	43	3	38	186	414	765	955	
				100	245	474	915	1115	
Kilbourne & Clarke Mfg. Co.	.0005	Fixed						287	
"	.001	"						1156	
"	.005	"						2890	
"	43	43		13	155	259	551	712	
Magnus Electric Co.	916	16	3	13	55	102	159	204	
				43	88	134	190	207	
"	917	17		8	63	137	202	255	
Malone-Lemmon Lab.	A44	20		29	132	251	372	481	
Moretone Radio Co.	11	11		13	57	109	163	209	
"	V11	11	1	13	54	94	136	172	
				52	90	131	169	206	
"	21	21		17	117	226	341	449	
"	V21	21	1	16	101	196	288	389	
				55	142	237	330	422	
"	43	43		31	227	434	646	847	
"	V43	43	1	26	212	416	625	812	
				63	251	451	659	844	
Mueller Instr. Co.	A237	15		31	87	180	282	362	2–9
National Co., Inc.		12	Gear	13	61	117	178	246	
"		25	"	15	99	225	345	490	
New York Coil Co.	.00025	Fixed						226	
"	.002	"						2060	
Pacent Electric Co., Inc.	200A	3		6	13	22	34	43	
"	200B	5		6	22	44	66	87	
"	200C	11		4	52	109	163	215	
"	200C	15		6	93	176	242	306	
"	200D	21		8	104	222	336	441	
"	200E	43		12	219	455	696	920	
Premier Electric Co.	23V	23	5	52	174	313	443	566	
				151	269	407	541	660	12
"	43V	43	5	57	292	557	830	1068	
				157	392	654	928	1162	12
Perfection Mach. & Mfg Co.		17		12	82	147	216	284	
		23	3	20	100	191	276	352	
				52	137	221	316	388	
"		43	3	25	172	332	494	663	
				57	206	377	542	700	
Radio Dev. & Mfg. Co.	VC99	13	Gear	8	56	128	197	261	9–10
(Veldar).	VC101	21	"	9	107	270	426	579	9–10
Radio Industries Corp.	450			10	17	43	104	222	1
(Rico).	423			27	41	67	164	635	1
Radio Stores Corp.	G	15		9	67	147	240	331	
(Haig & Haig)	H	23		17	101	242	393	534	
"	H	43		22	181	452	728	990	
Rathbun Mfg. Co.		3		4	7	12	17	19	
"		11		6	51	97	157	212	
"		11	3	12	45	112	161	210	
				19	71	120	172	227	
"		13		6	63	127	187	246	
"		15		16	78	152	228	307	
"		23		15	112	230	346	454	
"		43		15	231	450	667	866	
Sherman Rad. Distr. Co. (Kant-Short)		46	2	25	247	496	754	944	
				64	288	541	796	983	
Signal Elect. Mfg. Co.	R77	21		16	93	181	277	371	
"	132	21	2	13	84	125	282	381	
				22	88	131	288	387	
Stand-bi Radio Mfg. Co.	.0001	Fixed						42	
"	.00025	"						181	
"	.0005	"						374	
"	.001	"						756	
"	.0025	"						2460	
"	.005	"						3140	
"	.006	"						3380	

Manufacturer	Type	No. of plates	No. of plates in Vernier	Capacity (micro-microfarads) 0	25	50	75	100	Notes
Stern & Co., Inc. (Fesco)	....	3	......	2	7	21	30	37	....
"	....	11	......	7	57	117	152	196	....
"	....	23	......	19	117	232	344	456	....
"	....	43	......	20	227	456	692	938	....
Thordarson Elect. Mfg. Co.	R171	23	1	14	131	145	358	466	....
				15	135	154	370	474	....
United Mfg. & Distr. Co.	....	11	......	6	50	107	165	222	....
"	....	23	......	16	114	249	372	494	....
United Scientific Lab.	(U.S.L.)	23	......	13	100	204	321	431	....
Walnart Elect. Mfg. Co.	....	3	......	6	16	28	37	48	....
"	....	5	......	11	32	49	67	80	....
"	....	9	3	33	48	79	118	154	....
				51	76	115	154	185	....
"	....	13	......	14	62	144	199	269	....
"	....	17	......	22	83	169	255	333	....
"	....	19	3	14	86	168	249	328	....
				56	122	198	282	359	....
"	....	23	......	10	101	193	297	389	....
"	....	39	3	24	161	362	509	679	....
				61	196	367	546	711	....
"	....	43	......	33	192	383	581	767	....
Westwyre Co..........	G	11	......	6	54	108	161	205	....
"	F	17	......	7	77	167	247	323	....
"	E	23	......	15	110	221	344	461	....
"	D	43	......	12	214	441	666	859	....
"	117	17	......	34	94	173	261	335	....
"	110	23	......	31	80	245	318	467	....
"	100	43	......	47	248	430	713	927	....
Wireless Shop..........	20T	2	......	2	6	10	16	21	....
"	..130T	13	......	10	56	120	183	245	....
"	130MV	13	2	10	56	119	178	237	....
				20	66	122	190	249	....
"	170T	17	......	12	79	164	248	322	....
"	170MV	17	2	14	75	157	237	316	....
				24	86	166	246	326	....
"	230T	23	......	11	97	215	339	451	....
"	230MV	23	2	16	107	217	326	425	....
				29	122	221	337	429	....
"	310T	31	......	17	127	280	436	584	....
"	430T	43	......	21	201	431	642	856	....
"	630T	63	......	22	274	606	954	1271	....

Notes:—

1. Special type, variable, mica dielectric. 1a, "Adjustable fixed" type, i.e., adjustable to proper value, and allowed to remain as set.

2. Enclosed in metal case.

3. Enclosed in celluloid case.

4. Vernier consists of eccentric driving plates by forked arm on shaft.

5. No vernier; connections on back of instrument according to letters indicated (marked on case); enclosed.

6. Straight line type;

7. Special vernier construction.

8. Book type, mica dielectric, variable; capacity increases as dial rotates to 150 (270°). Values at 125 and 150 on the dial are given on second line.

9. Die-Cast Plates.

10. Cut-back plates to reduce minimum capacity and facilitate tuning at lower end of scale.

11. Double range secured by means of 2 sets of plates, either or both of which may be connected in circuit at the same time.

12. Mercury type.

HOW TO DESIGN A SUPER-HETERODYNE AND THE USE OF HONEYCOMB COILS

The problem of constructing a radio receiver for undamped, modulated continuous, and damped oscillations which is equally sensitive over a wavelength from 50 to 600 meters, which is capable of rapid adjustment from one wave to the other, and which does not distort or lose any characteristic note or tone inherent in the transmitter, has resulted in the super-heterodyne, as an attempted answer.

Great increase in signal strength is possible by means of the simple heterodyne method but there are difficulties encountered. The chief difficulty is the instability of the beat note which is a decided disadvantage in radiophone reception, on account of the attendant distortion. To illustrate this let us take for example a one million cycle wave heterodyned to 10,000 cycles. A variation of 10% in the beat frequency would represent only a 2% variation if the signal had been heterodyned to only 50,000 cycles. On account of this, the super-heterodyne reduces the frequency to a super-audible value.

A separate heterodyne is generally used to overcome the instability of the beat note. The filter used must be very selective; the coil must have very low resistance and be wound anti-capacity. The reason for such selectivity is as follows. If we consider, for instance, that the tuning circuit in a certain receiver is able to discriminate easily between waves differing in frequency by 5,000 cycles, assuming one of these waves to be 1,000,000 cycles, and our oscillator is set at 950,000 cycles, we would have as the intermediate or differential frequency in either case

$$1{,}000{,}000 - 950{,}000 = 50{,}000$$
$$1{,}005{,}000 - 950{,}000 = 55{,}000$$

The difference between the two waves before transformation was 0.1%, after transformation it became 1.0% or the selectivity has been increased in the ratio of about 1 to 10, i.e., a variation of 0.1% in the tuning circuit would cause a variation of 1.0% in the differential frequency.

It is this magnification of effects that gives to the circuit its great selectivity. The attainment of the greatest possible selectivity, however, results in a disadvantage which is brought out below.

Satisfactory quality and freedom from distortion of music cannot be very well obtained unless all voice frequencies are present up to about 5,000 cycles. This means that for satisfactory reception the transformers and filters must be able to pass frequencies ranging from

$$f + 5{,}000 \text{ to } f - 5{,}000$$

cycles, in which f is the carrier frequency. Now, if the filter has been designed for a carrier frequency of 50,000 cycles, it must pass frequencies ranging from 55,000 to

45,000 cycles. This range represents 20% of the carrier frequency, which is rather large. It seems therefore, that although the super-heterodyne would be ideal for C. W. reception, the attainment of extreme selectivity will result in lack of quality in radiophone reception.

It is impracticable, therefore, to use transformers designed for 20,000 or 30,000 cycles, since these frequencies are too close to the audible range and some of the harmonic side frequencies that would have to be transmitted to preserve the quality would be lost. We may consider, however, that fairly good efficiency in a transformer may be realized if we allow about a 10% variation from its peak frequency. Assuming all these values then we may write

$$f_1 - f_2 + 5{,}000 = 10\% \text{ or } 10 \times 5{,}000 = 50{,}000 \text{ cycles}$$

would in this case be the best intermediate frequency to use.

The filter consists of a parallel impedance resonant at 50,000 cycles. It may consist of an ordinary coil in parallel with a fixed condenser. The inductance required in the coil may be calculated from

$$f = 159.3 \div \sqrt{LC}$$

and for $f = 50$, and assuming C to be a fixed condenser, 0.001 μf we obtain for L a value 10,140 μh. The nearest value to this in honeycomb coils is the 400 turn coil.

The inductance required in the intermediate transformers may be arrived at approximately as follows. To obtain the best output of the tube we must make the impedance in the plate circuits equal to the plate resistance of the tube. For the UV-201A, 90 volts plate, –4.5 volts on the grid. this is about 11,000 ohms. Neglecting the transformer resistance we obtain

$$L = \frac{2\mu f}{R} = \frac{11{,}000}{6.28 + 50{,}000} = 0.035 \text{ henry or } 35{,}000 \mu h.$$

This is a first approximation, since we have neglected the coil resistance and capacity, and the mutual inductance between the transformer windings. The honeycomb coil having an inductance nearest to this value is the 750 turn coil. Used together with a 1500 turn coil (the largest made) the turn ratio would be 1 to 2.

In determining the values for the oscillator coils the same method is used as for determining the filter inductance. Assuming a 0.001 μf variable condenser the inductance required to cover the broadcasting range (550 to 1,350 kilocycles) is 83.6 μh.
The nearest honeycomb coil to this value is the 35 turn coil. Some makes of 35 turn coils may not have sufficient inductance so that it may be well to try a 50 turn coil (the next size).

This combination of coil and variable condenser may be placed in either the grid or the plate circuit of the oscillator, and a 35 turn coil used in the other circuit. The pick-up coil used in the loop circuit may be a 25 or 35 turn coil.

RADIO CONDENSERS

Sorting the Good From the Bad

(Continued from the August issue of Radiofax)

In this article we present a table giving the maximum capacities of these condensers, together with the equivalent series resistances and the corresponding phase differences. The capacities are given in micromicrofarads, the resistances in ohms, and the phase differences in minutes of arc.

As intimated in previous articles, dealing with condensers the values of resistance obtained for any condenser when measured directly at 1,000,000 cycles, will in general be very different from the value obtained when measured at 1,000 cycles and calculated for 1,000,000 cycles. It is believed that no one has the right to assume that the series resistance of a condenser varies inversely with the frequency. It may be well to repeat a little here. The phase difference of a condenser is given by

$$\psi = 0.36 \text{ frC}$$

in which ψ is the phase difference in degrees, f the frequency in kilocycles, r the resistance in ohms and C the capcity in mircofarads. We are considering a large change in the value of f. If everything else remained the same we would be justified in making the above assumption, but the fact remains that the value of the resistance varies somewhat, too, on account of the skin-effect at high frequencies. This would make the phase angle proportional to a power of the frequency greater than unity, and repudiate the above assumption, which calls for a constant value for ψ.

To illustrate this point, we happen to know of a condenser whose resistance as measured at 1,000 cycles is 125 ohms. Making the calculation for 1,000,000 cycles we obtain as the resistance at this frequency

$$125 \times \frac{1,000}{1,000,000} = 0.125 \text{ ohm}$$

The resistance of this same condenser was measured directly at 1,000,000 Cycles, and found it to be 0.8 ohm. The skin-effect, then, in this case, raises the resistance by 0.7 ohm.

It is not intimated in these articles that the measurements made at 1,000 cycles are not correct. They *are* correct—at 1,000 cycles. The error is made in computing the values for radio frequencies.

If a curve is plotted of resistance against frequency, we will obtain almost a straight line. The curvature is so slight that if plotted to a practical scale it will not be noticed. If we should double or triple the frequency we could calculate the effects at one frequency from knowing the effects at another frequency, but when it comes to calculating the effects at frequencies 1,000

times as great as those at which the effects are known, the effect of the slight curvature becomes appreciable.

All the measurements, the results of which are given in the table, were made **directly at radio frequencies and should not be compared with any measurements made at other than radio frequencies.**

The phase angle of a condenser may be regarded as a "figure of merit" of condensers regardless of the size. It is obvious from the formula that of two condensers having the same resistance, the larger one will have the larger phase angle.

TABLE OF CONDENSER CONSTANTS

Measured directly at 200 and 300 meters, and maximum condenser setting by an entirely new method.

Manufacturer	Type	No. of plates	Max Capacity $\mu\mu f$	Resistance (ohms)	Phase Difference (Minutes)	λ	Notes
Acme Apparatus Co.	....	29	478	0.7	11	200	8
Aerovox Wireless Corp.	.0005	Fixed	487	0.8	13	200	....
"	.001	"	999	0.8	18	300	....
"	.002	"	1842	0.4	24	200	....
"	.006	"	6020	0.4	74	200	....
Amplex Instrument Lab.	"Grid-	Denser"	392	0.7	9	200	1a
"	"	"	978	0.8	16	300	1a
Amsco Products Co., Inc.	....	23	377	1.0	13	200	....
"	....	23-3	406	0.9	12	200	....
"	....	43	691	0.9	13	300	....
"	....	43-3	756	1.4	23	300	....
Atwater-Kent Mfg. Co.	4270	19	347	1.2	14	200	2
"	....	16	282	1.5	14	200	2
Bruno Radio Corp.	....	22	520	0.8	13	200	11
Buell Mfg. Co. (Flewelling)	R	23	490	0.9	14	200	....
Caldbeck Tool & Mfg. Co.	....	23	353	1.2	13	200	6
Cardwell Mfg. Corp.	141B	11	250	1.5	12	200	....
"	152B	17	374	1.2	15	200	....
"	123B	21	476	0.9	13	200	....
"	137B	41	961	0.7	14	300	....
Carter Radio Co.	.01	Fixed	......	0.7	......	200	....
Chelten Electric Co.	820	11	253	1.5	12	200	....
"	815	17	388	1.0	12	200	....
"	810	23	517	0.8	13	200	....
"	800	23-9	559	0.8	14	200	....
"	805	45	1017	0.6	13	300	....
"	790	45-9	1043	0.5	12	300	....
Connecticut Tel. & Elec. Co.	D-10	3	850	1.3	24	300	5
Crosley Mfg. Co.	....	2	747	0.5	11	200	8
Dayton Fan & Motor Co.	5017	23-1	501	0.7	12	200	....
DeForest Radio Tel.&Tel. Co.	CV-600	25-1	560	0.9	17	200	....
"	CV-1503	31-2	1133	0.6	14	300	....
"	CV-1003	45-2	1575	0.6	19	300	....
Dubilier Condenser & Radio	.00025	Fixed	288	1.5	14	200	....
Corp.	.0003	"	300	1.0	10	200	....
" (Type 601)	.0005	"	480	0.8	12	200	....
"	.001	"	858	0.8	16	300	....
"	.0015	"	1900	0.4	23	200	....
"	.003	"	3095	0.4	36	200	....
"	.004	"	4100	0.1	13	200	....
"	.005	"	5020	0.4	60	200	....
"	.006	"	6240	0.3	61	200	....
"	.0075	"	7430	0.2	43	200	....
Duplex Engine Gov. Co.	DR-23	23	534	0.7	12	200	....
Electrical Research Lab.	.00025	Fixed	250	1.8	14	200	....
" (Erla)	.00035	"	310	1.7	17	200	....
"	.0005	"	500	1.0	11	300	....

Manufacturer	Type	No. of plates	Max. Capacity $\mu\mu f$	Resistance (ohms)	Phase Difference (Minutes)	λ	Notes
Electrical Research Lab	.0008	"	750	0.9	14	300	....
"	.001	"	999	0.5	16	200	....
"	.0025	"	2500	0.4	32	200	....
"	.005	"	4900	0.4	64	200	....
"	.006	"	6000	0.4	78	200	....
Elgin Tool Works, Inc	....	17	316	1.6	16	200	....
"	....	23-2	449	0.9	13	200	....
"	....	43-2	849	0.8	15	300	....
Fada (F. A. D. Andrea)	....	13	319	1.3	13	200	....
"	....	23	498	0.8	13	200	....
Federal Tel. & Tel. Co	45	11	276	1.5	14	200	....
"	82	11	265	2.0	17	200	2
"	46	21	514	0.8	13	200	....
"	83	21	513	1.0	17	200	2
"	47	43	1054	0.7	15	300	....
"	85	43	1105	0.8	20	300	2
Framingham Co	10	14	244	1.7	14	200	....
"	11	14-3	292	1.5	14	200	....
"	12	26-3	542	0.7	12	200	....
"	14	50	956	0.8	16	300	....
"	15	50-3	1011	0.7	15	300	....
Freed-Eisemann Corp	258	13	288	1.0	9	200	....
Freshman & Co	.0003	....	330	2.2	23	200	12
Gardiner & Hepburn	13	13	262	1.9	16	200	7
(Continental Lo-Loss)	18	18	347	1.0	11	200	7
"	25	25	500	0.8	12	200	7
"	45	45	1102	0.8	18	300	7
General Instrument Corp	46A	13	307	1.2	12	200	10
"	46D	21	499	0.6	10	200	10
"	46F	43	1029	0.6	13	300	10
General Radio Co	247H	26	506	0.7	11	200	gear
"	239G	33	1047	0.4	9	300	"
Gilfillan Bros., Inc	R400	17	317	1.2	12	200	....
"	R375	23	404	0.9	12	200	....
"	R750	23-3	422	1.0	14	200	....
"	R350	43	737	0.9	14	300	....
"	R725	43-3	862	0.7	14	300	....
Hammarlund Mfg. Co	.00025	11	221	1.8	13	200	4
"	.00038	17	383	1.0	12	200	4
"	.0005	23	501	0.8	13	200	4
"	.001	43	984	0.5	11	300	4
Hartford Instrument Co.	23SP	23	431	1.0	14	200	....
(Sexton)	23SD	21-3	432	0.8	12	200	....
Heath Radio & Elec. Co	.0005	24-1	550	0.9	14	200	....
Horne Elect. & Mfg. Co	355	18-3	447	1.0	14	200	....
Kellogg Swbd. & Supply Co.	601	11-3	454	0.8	12	200	....
"	603	23-3	884	0.7	14	300	....
"	605	43-3	1115	0.7	17	300	....
Kilbourne & Clarke Mfg. Co.	.0005	Fixed	287	1.4	13	200	....
"	.001	"	1156	0.8	21	300	....
"	.005	"	2890	0.4	34	200	....
"	43	43	712	1.1	16	300	....
"	45	45-2	......	0.7	......	300	....
Magnus Elect. Co	916	13-3	207	1.6	11	200	....
"	917	17	255	1.5	13	200	....
Malone-Lemmon Lab	A-44	20	481	0.7	11	200	....
Moretone Radio Co	21	21	449	0.7	10	200	....
"	V-21	21-1	422	1.0	14	200	....
"	43	43	847	1.0	18	300	....
"	V-43	43-1	844	0.8	15	300	....
National Co., Inc	....	12	246	1.8	15	200	gear
"	....	25	490	0.8	13	200	"
New York Coil Co	.002	Fixed	2060	0.5	35	200	....
Pacent Elect. Co., Inc	200C	15	306	1.6	16	200	....
"	200D	21	441	0.8	11	200	....

Manufacturers	Type	No. of plates	Max. Capacity $\mu\mu f$	Resistance (ohms)	Phase Difference (Minutes)	λ	Notes
Pacent Elect. Co., Inc.......	200E	43	920	0.6	12	300	....
Perfection Mach. & Mfg. Co.	....	17	284	1.4	13	200	....
"	....	23-3	300	0.8	10	200	....
"	....	43-3	700	0.8	13	300	....
Radio Condenser Co.........	....	23	500	0.8	......	200	11
("Certified")	....	45	......	0.7	......	300	....
Radio Dev. & Mfg. Co.......	VC-99	13	261	0.8	7	200	9-10
"	VC-101	21	579	0.8	15	200	"
Radio Industries Corp.......	423	"Rico"	222	0.7	3	300	1
	450	"	635	1.1	23	200	1
Radio Stores Corp...........	G	15	331	0.9	9	200	....
(Haig & Haig)..........	H	23	534	0.6	11	200	....
"	H	43	990	0.5	11	300	....
Rathbun Mfg. Co...........	....	13	246	1.1	9	200	....
"	....	15	307	1.1	11	200	....
"	....	23	475	0.9	13	200	....
"	....	23-3	480	0.7	......	200	....
"	....	43	935	0.8	16	300	....
Sherman Radio Distrib. Co...	....	46-2	983	0.7	15	300	....
(Kant-Short)..........	.0005	23-3	......	0.7	......	200	....
Signal Elect. Mfg. Co........	R-77	21	371	1.2	14	200	....
"	132	21-2	387	1.3	16	200	....
Stand-bi Radio Mfg. Co.....	.0025	Fixed	2460	2.4	195	200	....
"	.005	"	3140	1.8	189	200	....
"	.006	"	3680	1.5	177	200	....
Stern & Co. (Fesco)..........	....	23	456	0.8	12	200	....
"	....	43	938	0.8	17	300	....
Thordarson Elect. Mfg. Co...	R-171	23-1	474	0.8	12	200	....
" ...	R-161	23	460	0.9	13	200	....
United Mfg. & Dist. Co......	....	23	494	0.7	12	200	....
United Scientific Lab.(U.S.L.)	....	23	431	0.7	9	200	....
Walnart Elect. Mfg. Co......	....	13	269	1.2	10	200	....
"	....	17	333	1.0	11	200	....
"	....	19-3	359	1.0	12	200	....
"	....	23	389	1.0	14	200	....
"	....	39-3	711	0.8	13	300	....
"	....	43	767	0.8	13	300	....
Westwyre Co..............	F	17	323	1.1	12	200	....
"	E	23	461	0.8	13	200	....
"	D	43	859	0.7	13	300	....
"	117	17	335	1.3	15	200	....
"	110	23	467	1.2	18	200	....
Wireless Shop.............	130T	13	245	1.4	11	200	....
"	130MV	13-2	249	1.7	13	200	....
"	170T	17	322	2.0	21	200	....
"	170MV	17-2	326	1.0	11	200	....
"	230T	23	451	0.9	14	200	....
"	230MV	23-2	429	0.9	12	200	....
"	310T	31	584	0.8	15	200	....
"	430T	43	856	0.6	12	300	....
"	630T	63	1271	0.7	19	300	....

1. Special type, variable, mica dielectric. 1a, "Adjustable fixed" type, i.e., adjustable to proper value, and allowed to remain as set.
2. Enclosed in metal case. 3. Enclosed in celluloid case.
4. Vernier consists of eccentric driving plates by forked arm on shaft.
5. No vernier; connections on back of instrument according to letters indicated (marked on case); enclosed.
6. Straight line type; 7. Special vernier construction.
8. Book type, mica dielectric, variable; capacity increases as dial rotates to 150 (270°). Values at 125 and 150 on the dial are given on second line.
9. Die-Cast Plates. 10. Cut-back plates to reduce minimum capacity and facilitate tuning at lower end of scale.
11. Double range secured by means of 2 sets of plates, either or both of which may be connected in circuit at the same time.
12. Mercury type.

RESISTANCE COUPLING
For Audio Frequency Amplifiers

The present day interest in resistance coupled audio frequency amplifiers owes its existence to well defined conditions in the radio industry. It is mainly an evidence of the steady and intensive striving for better quality in reception. The method is not new; it is practically as old as the amplifier tube.

Resistance coupling is one of the many known means of transferring current fluctuations between the tubes of a cascade amplifier. Its efficiency per stage is below that of transformer coupling and for that reason the latter method soon displaced the former in popularity.

This shifting of favor occurred before the days of radio-phone broadcasting, when practically all radio communication was in telegraphic code. For such work, the requirements of a coupling device were far less severe than now, due to the fact that only one frequency was involved. Today our amplifiers must faithfully respond to a wide variety of frequencies covering the entire musical scale.

Great improvements have been made in audio transformers, but none of them will amplify equally over the range of frequencies used. They will give greater amplification at one frequency than at another. They will, therefore, exaggerate certain notes and suppress others. They may in some cases give no response at all for frequencies near the extreme ends of the musical scale.

In well-designed audio transformers these short comings are not serious and are only noticeable to an extremely critical ear.

There was a time when the volume of sound delivered by a radio receiver was the sole criterion of its merit. The novelty of the thing was sufficient to out weigh any deficiencies in quality. In the early days the broadcasting stations themselves introduced a great deal of distortion, so that even if a perfect receiver were available the quality of reproduction would have been unsatisfactory.

Today the broadcasting stations are transmitting very high-grade programs and the efficiency of their apparatus has been increased to such an extent that with an equally efficient receiver the reproduction will be accepted as practically perfect by even the most critical ear.

In searching for methods for attaining undistorted amplification, the once-discarded resistance coupling idea was tried and was found to be extremely promising. It was realized that three stages of amplification would be required to attain volume equal to two transformer coupled stages. But this is not a serious matter today, for the modern tube draws very little filament current so that the extra drain on the "A" battery is negligible.

The cost of tubes has been materially reduced below the 1922 figure, so that the cost of three tubes today is less than the price of two a year or so ago. Fixed high resistances of permanent and dependable rating are now readily available, and their cost added to the price of the fixed condenser, which is also needed for resistance coupling, makes the total cost of the interstage apparatus less than the price of a transformer.

Additional "B" battery voltage must be used when resistance coupling is employed; three 45-volt units being required instead of two. Here too the cost has recently been reduced, so that the extra battery is not as big a handicap as heretofore.

The circuit diagram for a detector and three stages of resistance coupled amplification is shown in Fig. 1. The resistances R_1, R_3, and R_5 should have a value about 1-10 megohm (100,000 ohms). The resistances R_2, R_4, and R_6 are grid leaks. Their value should be about 1, 0.25, and 0.05 megohms, respectively.

Resistance R_7 should have a value between 5,000 and 50,000 ohms. This resistance is used to reduce the plate current in the output circuit of the last tube to a value for which the telephone or loud speaker is designed. A better method of handling the plate current of the last tube would be to apply to it a lower voltage as shown by dotted line. In such case the resistance R_7 and the wire xy would be eliminated.

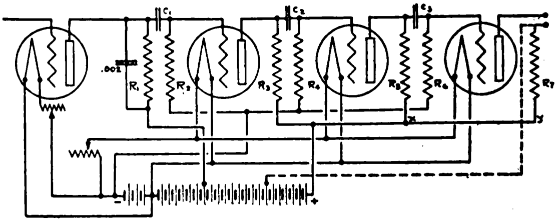


Fig. 1. Three-stage Resistance Coupled Avdio Frequency Amplifier

The condensers C_1, C_2 and C_3 are not critical in their operation and can have almost any value between .003 and 0.5 microfarad.

The theory of operation can be explained by reference to tubes 2 and 3 above, with their coupling resistance and grid leak R_3 and R_4. Fluctuations in the plate current of tube 2 caused by the output from the detector produce corresponding differences in potential across the resistance R_3. This can be shown by Ohms law for the relation of current, voltage and resistance.

The differences in potential across R_3 are impressed on one side of condenser C_2. This varying positive potential induces a corresponding fluctuating negative

potential on the grid side of the condenser. This negative fluctuation actuates the grid of the third tube. Resistance R_4 serves to prevent an accumulation of excessive charge on the grid. The condenser C_2 in addition to its above mentioned function also prevents the high plate voltage of tube 2 getting to the grid of tube 3.

The principle of supplying a varying negative charge to the grid of the tube effects an economy in "B" battery drain for the signal causes the plate current to modulate down, in other words maximum current flows when there is no signal fluctuation on the grid. When the grid receives a charge from the coupling condenser, its effect is shown in the plate circuit by a corresponding decrease in the current flowing in that circuit.

The amount of current drawn from the "B" battery by a resistance coupled amplifier can be very closely calculated from the characteristic curve of the tubes used and an application of Ohms law.

A UV-201-A tube with 90 volts on the plate and with the grid at zero potential showed a current drain of 6.4 milliamperes (.0064 amperes). When the primary of an audio frequency transformer was inserted in the plate circuit, other conditions remaining the same, the current drain was reduced to 4.8 milliamperes (.0048 amperes).

The transformer was removed and a fixed resistance of 100,000 ohms (the value used in resistance coupled amplifiers) was inserted in its place. The current drain was then reduced to 0.8 milliamperes (.0008 amperes). When the "B" voltage was increased to 135 volts the plate current increased to 1.2 milliamperes (.0012 amperes). Thus it is seen that the use of resistance coupling does not severely tax the "B" battery.

The value 1.2 milliamperes is, of course, for only one tube whereas three are generally used. The total current for the three tubes would be 3.6 milliamperes.

When transformer coupling is used with a "C" battery of 4½ volts to give a negative bias and thus reduce the plate current, the average drain on the "B" battery for one tube is about 2.4 milliamperes and for two tubes 4.8 milliamperes.

If we take into consideration the plate voltage and convert the above values to power units we will have for resistance coupling:

$$.0036 \times 135 = .4860 \text{ watts}$$

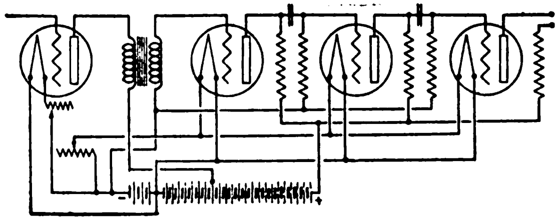
and for transformer coupling

$$.0048 \times 90 = .4320 \text{ watts}$$

This shows that the resistance coupled amplifier draws slightly greater power than the transformer coupling, but when the down modulation characteristics of the former is taken into consideration the two values become about equal. The drain on the "A" battery, however, is ¼ ampere greater for resistance coupling.

A resistance coupled amplifier can not be directly connected to the output of a crystal detector, because the very minute current induced in the antenna and rectified by the crystal is insufficient to cause an appreciable change in potential across the coupling resistance.

One stage of transformer coupling should be used between the crystal and the resistance coupled amplifier. Two stages of resistance coupling in addition will be sufficient in this case.



The diagram in Fig. 2 shows a circuit having one stage of transformer coupling and two stages of resistance coupling. This arrangement is a very satisfactory one and if care is exercised in the selection of the transformer, music of excellent quality will reward the builder.

Since the function of the grid leak is to allow the dissipation of excessive charge, it follows that the use of the highest possible resistance will insure the loudest signal. If, however, the resistance be made too high the tubes will perform improperly, causing distortion or they may cease to function entirely.

If howling occurs in a resistance coupled amplifier, an adjustment of the grid leak values may remove the difficulty. If not, it may be necessary to increase the last, or last two coupling resistances up to possibly 250,000 ohms.

Since resistance coupling is non-inductive there should not be any difficulty from undesirable stray coupling between stages and therefore if howling occurs it is reasonable to assume that it is due to the tubes having unusual characteristics. The adjustments mentioned above will remove the trouble from this source.

It should be noted that a higher voltage than generally used must be applied to the detector circuit when resistance coupling is used in place of a transformer. The voltage must be increased to compensate for the loss in the added resistance. For this reason a jack connection should not be used in the detector circuit, unless the builder makes provision for reducing the plate voltage when the comparatively low resistance phones are substituted for the high coupling resistance.

RESISTANCE HIGH AT LOW SETTINGS OF VARIABLE CONDENSERS

On the whole the values of resistance obtained in our test for the different condensers have been a great surprise to many, including the manufacturers. This surprise lay mainly in the fact that the resistances are shown to be many times greater than was ordinarily believed. This applies to *all* the condensers. In the past, on the basis of assuming the power factor or phase difference to remain constant for all frequencies, the resistances as determined from measurements made at audio frequencies gave values in the neighborhood of 0.1 ohm or less. Resistance variation methods, or other methods employing standard condensers whose resistances were assumed zero, also gave values which might be as much as several hundred per cent from the true value.

The method used in these tests gave results as close as 0.01 ohm, as proven by check measurements made on known resistances.

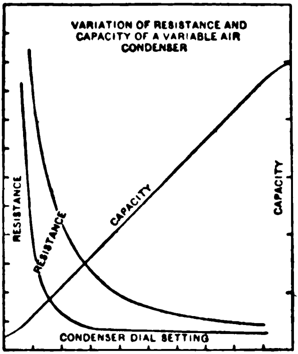
The total range of resistances in the table is from 2.2 ohms to 0.4 ohm, from the highest to the lowest. As a result the resistance of even the poorest condenser is small compared with the resistances of coils and loops used with condensers in circuits carrying oscillatory currents. The resistances of coils and loops may run as high as 30 to 40 ohms, or higher, so that the reduction of the total circuit resistance obtained by substituting this best condenser for this worst one would only be about 4 or 5 per cent.

If averages are computed from the table, for all condensers of the "low-loss" type, having capacities in the neighborhood of 500 $\mu\mu f$, we obtain the value 0.33 ohm. If we do the same for the "old-style" types, we obtain the value of 0.97 ohm. The average reduction is then about ¼ ohm, or about 25% of the condenser resistance. This reduction, however, represents only a 0.5% reduction in the total circuit resistance. A similar result will be obtained if averages are computed for condensers of capacities around 1,000 $\mu\mu f$.

The table shows also that smaller condensers of the same design and make, and which differ only in their number of plates, have the higher resistance.

The most important point in connection with condenser resistance is the variation of this quantity with the setting of the plates, that is, with the dial setting. Figure 1 shows the general shape of the curve.

The resistance does not change much (lower curve as the plates are moved out until we reach a dial reading of about 25, at which the curve bends sharply upward, reaching a resistance as high as 20 ohms at a dial setting of 5.



The lesson taught by this curve is that condensers should not be used at the very low dial settings, as then the resistance jumps up to such high values that it becomes a serious matter. Proper circuit design requires, then, that the inductance used with the condenser be so designed as to cover the wave range required without having to use the condenser at low dial settings.

The higher curve is for a condenser whose resistance at a dial setting of 100 is higher than that on the lower curve A. The advantage of "low-loss" design is shown by a comparison of these two curves. Although the difference in resistance between the two condensers is small at the high dial settings, the resistance of the "low-loss" type rises much less rapidly as the plates are turned out.

The small differences existing between the two types of condensers gives rise to an idea not generally known before, and that is, that condensers having low losses can be constructed with solid endplates, if the material used is properly chosen, and the instrument is well constructed. This further emphasizes the statement made several times in our writings that the more serious cause of condenser resistance is not in the dielectric but in the skin-effect in the plates and elsewhere. It also shows that resistances between contacts and joints is very small. Where condensers have been measured at 1,000 cycles, the resistances calculated from these values for 1,000,000 cycles would give figures based on dielectric effects and contact resistance only, neglecting the skin-effect. The figures in this case often run about 0.1 ohm, whereas the true resistance might be 0.7 or 0.8 ohm. Dielectric hysteresis (or absorption) therefore may account for only as small an amount as 10 to 20 per cent of the total resistance.

The great need for "low-loss" condensers is indicated by the behavior at low dial settings as explained above. Since a great deal of the resistance is due to skin effect, it is our opinion that low resistances may be obtained at low dial settings by properly proportioning the dimensions of the plates. This is a suggested field of research for some abitious manufacturer or experimenter. But more serious than this, at the present time, is the need for coils and loops that have resistances as low as the resistances of condensers, and not 10 or 20, or 50 times as great.

McCAA ANTI-STATIC DEVICES

The radio fan will welcome with pleasure any device which tends to reduce interference from static disturbances—if it does not destroy his receiving range. Dr. Galen McCaa has experimented for several years on this very subject, and has at last presented a device which, according to recent issues of *QST*, is satisfactory. Doubtless many of our own readers will want to experiment with these circuits, especially since the static season is rapidly approaching. The device is intended for use primarily on circuits using radio-frequency amplification or a non-oscillating detector. It is not advised for use with regenerative circuits. It is well to state also that static is not completely eliminated, but is so reduced in volume that its presence is not noticed.

To understand the McCaa anti-static circuits in which vacuum tubes are used, the reader must understand the difference between signals and static. Dr. McCaa gives in his notes a very good explanation, and the following is simply an abstract of those notes. Let us assume that a receiving station is listening for a 300-meter, continuous-wave telegraph signal, using an ordinary two-circuit arrangement tuned by a series condenser on the primary side. Naturally the operator will tune the antenna circuit to 300 meters, so as to obtain the best signal strength. The antenna is then in condition ot oscillate at 300 meters when a signal comes along—but it will also oscillate at 300 meters when "shocked" or "jolted" electrically in any way. This is readily understood when one considers the mechanical analogy. A tuning fork constructed to vibrate at one frequency will respond to that frequency when it is created by a piano or another similar tuning fork. This represents the sending station broadcasting a frequency to which the receiving set is tuned. But suppose the original tuning fork is struck by a mallet—the same note is given out which was given out in the first case. It is the note to which the fork is tuned. In exactly the same way, the receiving set is caused to vibrate at the one frequency even when the vibration is caused by a severe electrical jolt, such as static.

Now static discharges and most "power leaks," act as "shock excitors" of receiving antennas within their range, but these disturbances do not have any definite wave length of their own. This creates a difficult situation, because we must tune the antenna to the wave length of our signal—or near it; but as soon as this is done we find the static effects in the antenna at the same wave length.

It would be a very fine thing if we could tune the antenna to the wave length of the signal, yet keep the static tune somewhere else. *That* is what the first of the McCaa devices does.

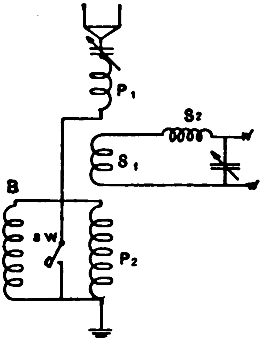


Fig. 1

The theory of the variometer is fairly well known to the layman. In one position of the coils, maximum inductance is obtained because the magnetic fields of the two aid each other. In the reverse position the fields of the two coils "buck" each other and minimum inductance is obtained. This principle is also used.

In Fig. 1 suppose that the switch is closed and the antenna circuit is tuned to the desired signal. Naturally the signal is induced in the secondary and so is the static, for it causes the circuit to vibrate at the signal frequency. Now let us open the switch, placing the coil P_2 into action. We can now change the coupling of the two primaries with the secondary until they balance each other out and the secondary receives neither signal nor static. Two things have happened, we have shifted the antenna tune by cutting in the additional primary and we have "bucked out" the static and signal both. Now then the trick is to regain the signal without the static.

A coil B of large inductance is shunted across P_2. This inductance may be five or more times as large as the inductance P_2 and hence has little effect on the system. Electric energy always tends to follow the easiest path—that is the one offering the least impedance to the current. A large coil has high inductance and high

resistance and as a result high impedance. Hence the energy in the antenna circuit flows more readily through P_2 than through this high impedance. If, however, we may lower the impedance of this coil by any means whatever, more energy flows through it and the system becomes unbalanced. At this point we make use of the variometer principle and neutralize the high inductance by an equal opposing high inductance. This is an electrical means of accomplishing the same results which the switch produces. However, we must energize coil C in some manner so as to produce this neutralizing field, and this is accomplished, as shown in Fig. 2, by a vacuum tube oscillator. This circuit is tuned to the signal frequency and we have a complete McCaa receiver. Coil C is called the "driver."

The field of the driver coil alternately adds to and subtracts from the field of the coil B. The effect of this is to make the inductance of B change at an audio frequency. One can see that if the driver-coil field is strong enough, this will mean that once per cycle the inductance of B will approach zero. When that happens B is no longer a choke coil of high impedance, but is merely a very low resistance. We will now assume the condition that B is acting as a short-circuiting device, and that as a result the signal energy is flowing in the antenna circuit and, of course, static with it. Now suppose that the oscillator is shut off for a moment. The antenna is now tuned from the incoming signal (because P_2 is in the circuit) and the static is kept out of the secondary circuit because of the balancing action of P_1, P_2 and S. Even though no energy reaches the secondary circuit we have done nothing to keep it out of the primary circuit, and the incoming signal causes a voltage drop across P_2 and hence across B. This may be hard to grasp, but a little careful thought will show that the statements are true.

Let us now start the oscillator and tighten the coupling to B until we are putting into B an opposing field just equal to that created in B by the received signal. It is evident that for voltages equal to or less than those of the received signal B is out of the circuit and P_2 is short circuited. Such conditions permit these currents to produce effects on the secondary. The signal will then appear in the secondary and along with it such small amounts of static as do not represent any voltage above the signal voltage. The tendency is toward a one-to-one ratio of signal and static. This is really an excellent condition, though hard to believe at first. In code work the operator receives the impression that the static disturbances have disappeared.

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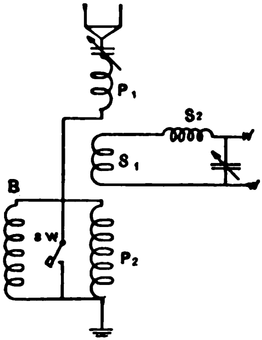

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The field of the driver coil alternately adds to and subtracts from the field of the coil B. The effect of this is to make the inductance of B change at an audio frequency. One can see that if the driver-coil field is strong enough, this will mean that once per cycle the inductance of B will approach zero. When that happens B is no longer a choke coil of high impedance, but is merely a very low resistance. We will now assume the condition that B is acting as a short-circuiting device, and that as a result the signal energy is flowing in the antenna circuit and, of course, static with it. Now suppose that the oscillator is shut off for a moment. The antenna is now tuned from the incoming signal (because P_2 is in the circuit) and the static is kept out of the secondary circuit because of the balancing action of P_1, P_2 and S. Even though no energy reaches the secondary circuit we have done nothing to keep it out of the primary circuit, and the incoming signal causes a voltage drop across P_2 and hence across B. This may be hard to grasp, but a little careful thought will show that the statements are true.

Let us now start the oscillator and tighten the coupling to B until we are putting into B an opposing field just equal to that created in B by the received signal. It is evident that for voltages equal to or less than those of the received signal B is out of the circuit and P_2 is short circuited. Such conditions permit these currents to produce effects on the secondary. The signal will then appear in the secondary and along with it such small amounts of static as do not represent any voltage above the signal voltage. The tendency is toward a one-to-one ratio of signal and static. This is really an excellent condition, though hard to believe at first. In code work the operator receives the impression that the static disturbances have disappeared.

The system so far discussed used a "driver" or oscillator to produce the bucking field operating on coil B. This is very good for telegraph work if the beat-frequency is made audible and can be used for telephony if the beat is made super-audible. However, it is readily seen that the weak sounds of radio telephony will be overridden by static and that the field used "to modulate" the field of B should vary exactly in the fashion of the received radiophone currents—that is, we must use a magnetic field that is modulated exactly as is the carrier wave of the station we are listening to. One method of doing this is shown in Fig. 2. The incoming signal controls the grid of the tube, thereby causing the field of the plate coil to vary. This in turn operates coil B and allows the signal to enter the secondary in accordance with the received voltage. Of course, static enters too—but at no instant does the static voltage in the secondary exceed the signal voltage. In other words, the static is also "modulated."

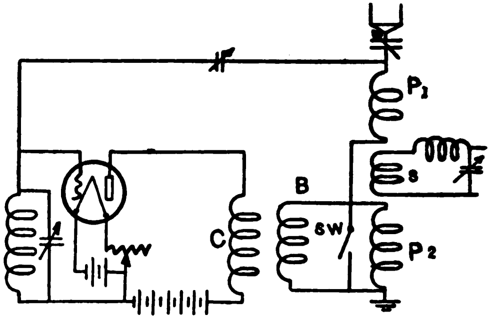


Fig. 2

The reader will notice that as long as the general principles of this circuit are followed there are many ways of accomplishing the desired results. Furthermore, there is no use in trying to eliminate static at the antenna circuit if the rest of the apparatus picks up large amounts of it. In order to prevent this sort of thing, the receiving set should be thoroughly shielded. The method is the usual one—a copper-lined box with the coils kept away from the shielding and with as few and as small openings as possible. The entire shield should be grounded.

We will now proceed to give some constructional dimensions for the so-called "Repeater system." This discussion refers entirely to the circuit shown in Fig. 3. The dimensions given are not supposed to be final, they are not even representative of any great amount of effort in this direction, for most of the work has been done in the direction of circuit-action, rather than the details of best coil designs, etc. The experimenter may improve upon these dimensions, but the circuit as presented works very well in the broadcast range of frequencies.

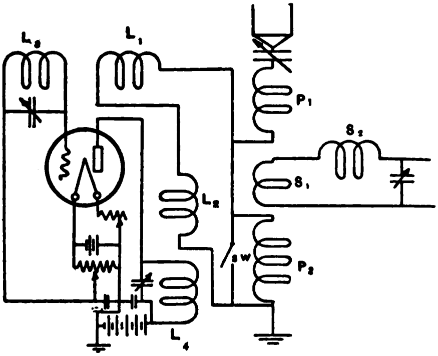


Fig. 3

P, P_2 S, L_3 and L_4 are coils having an inductance of 169 microhenries. This is a 50-turn, honeycomb coil. L_1 is a single layer coil wound on a 2-inch cylinder and having from 5 to 10 turns of No. 22 wire. L_2 is variable, and is also wound on a 2-inch diameter tube. It has from 50 to 75 turns. A tapped honeycomb coil is suitable. S is the ordinary size of secondary coil though much less interference is obtained by having a smaller number of turns in the coupled circuit and placing the rest at S_2, as shown.

The device is put into operation by first closing the switch SW. Tune in a station in the usual manner, by means of the variable condensers in the primary and secondary circuits. Now open the switch SW and change the coupling between both P_1 and P_2, until nothing is heard in the secondary circuit, indicating

that both the static and signal have been balanced out. If the static does not balance out, one of several things may be wrong. Perhaps the ground connection is not good. Waterpipe and steam pipes are not always the best grounds. Perhaps the trouble lies in the fact that P_1 and P_2 may be too close to S. They should stay at least ½ inch away from S. Here it is advisable to state that the simple circuit shown in Fig. 3 cannot eliminate such things as violent static and street car disturbances, for the very reason that there are some static couplings not guarded against. For the one who wants to do a complete job, several more complex circuits have been developed and operated with complete success.

However, assuming that a fair static balance has been secured, proceed by turning on the filament of the repeater tube and begin to tune its grid and plate circuits, trying various degrees of coupling between these circuits and the coils L_1, L_2. The first attempt at an adjustment of this sort will be rather tedious, because the operator will not know what values of coupling are to be used. After the correct grid coupling is found, it may be left alone, the whole device being adjusted by tuning the grid and plate circuits with a little final adjustment of the plate coupling.

This sounds rather complicated, especially as the plate circuit must always be kept a little off tune to keep the repeater tube from oscillating. As a matter of fact the circuit as shown is too complex to handle with pleasure but it is perfectly easy to build it in simpler form. The secondary circuit may be made to operate from the same control knob as the grid circuit of the repeater. The grid coupling can be left alone after one setting. The plate coupling can be set at an average point for most work and never needs a great deal of adjusting anyway. This leaves the plate circuit tuning condenser of the repeater; the double tuning condenser for the two grid circuits; and the broad-tuning, antenna condenser. There remains then three controls with plenty of room for improvement.

Up to the present time, we have not carried on any experiments in our own laboratory on this device. Those who have tried it are very enthusiastic over the results obtained. We are indebted to *QST* for much of the reliable information available on these circuits, and have freely consulted their recent publications in preparing this article. As we have mentioned before, more work was done on the actual circuits than on the mechanical design, and if any of our readers find new arrangements for simplifying the control operations we would be glad to hear about them.

FOREIGN BROADCASTING STATIONS
Not Included in Complete List

The following list of broadcasting stations in foreign countries is compiled from the information in the files of the electrical division of the Bureau of Navigation. It includes only those stations which broadcast programs for popular reception, though many of the stations included do so only as a minor part of their business.

Location	Operated by	Call	Wave Length	Power Watts
	Austria			
Vienna.............	Technologische Gewerbmuseum..	"Radio Wien"	700	100
Vienna.............	Radio Hekaphon...............	OHW	600	......
	Belgium			
Brussels............	No data.......................	SRB	405	......
Brussels............	No data.......................	BAV	900 1100	....
Brussels............	Radio Electrique..............	....	265	......
	Brazil			
Rio de Janeiro......	Praia Vermelha................	No data	....	500
Rio de Janeiro......	Marconi (Radio Sociedade do Rio de Janeiro)..................	No data	....	6000
Sao Paulo..........	Radio Bondeirantes............	No data	....	10,000
Belle Horisantes.....	National Telegraph Service......	No data	....	500
	Chile			
Valparaiso..........	Senor Placi do Munoz Rojas.....	No data	....	......
Santiago............	Radio Corporation of Chile......	CRC	400 460	....
Vina del Mar.......	Radio Corporation of Chile......	ABC	400	......
	China			
Hongkong..........	Hongkong Hotel Co............	....	....	......
Hongkong..........	Radio Communication Co.(Orient) (Ltd.)......................	....	....	......
Shanghai...........	The Evening News............	....	....	......
Macao.............	(Portuguese).................	....	....	......
	Curacao, British West Indies			
Curacao............	Department of Finance.........	....	....	......
	Czechoslovakia			
Kbely..............	Radio Journal..................	None	1100	1000
Prague.............	No data.......................	PRG	1800 4500	10,000
Brunn..............	No data.......................	OKB	1800	1000
	Denmark			
Lyngby............	Danish Government............	OXE	2400	2500
	Finland			
Tammerfors........	Amateur Radio Society..........	3NB	300	20
Skatudden..........	Nuoren Voiman Luton Radioyhdistys "Radio Division".......	....	450	75
	France			
Paris..............	Eiffel Tower..................	FL	2600	4000
Paris..............	Escole Superieure des P. T. & T..	ESP	450	350
Tours..............	French Government...........	YG	2500	500
La Doua (Lyons)....	French Government...........	YN	480 3100	500
Paris..............	Levallois (Radiola)...........	SFR	1780	2000
Nice...............	French Government...........	None	460	......
Issy-sur-Moulineaux.	French Government...........	None	1600	......
Bourges...........	French Government...........	None	900	......
Abbeville..........	French Government...........	None	900	......
Paris..............	No data.......................	8AJ	1780	......

Continued on next page

Location	Operated by	Call	Wave Length	Power Watts
	Germany			
Berlin.............	Konigswusterhausen.............	LP	2800	......
Berlin.............	Vox Haus.....................	None	450	1500
Leipsig............	Mitteldeutsche Rundfunk, A. G..	None	436	1000 1500
Frankfurt..........	Sudwestdeutsche Rundfunkienst..	None	460	......
Hamburg............	Nordischer Rundfunk, A. G......	None	392	......
Breslau............	Schlesische Rundfunk, A. G......	None	415	......
Konigsburg.........	Ostmarken Rundfunk, A. G......	None	460	......
Stuttgart..........	Suddeutsche Rundfunkdienst, A. G.........................	None	437	......
Munich.............	Deutsche Stunde in Bayern......	None	485	1500
Eberswalde.........	No data.......................	....	2930	......
	India			
Calcutta...........	Radio Club (2BZ) operated by Marconi.....................	5AFO	425	......
	Italy			
Rome...............	No data.......................	ICD	3200	......
Rome...............	Ing. Ranieri..................	None	350 450	....
Centocello.........	No data.......................	None	2900	......
	Jugoslavia			
Belgrade...........	No data.......................	....	1625	......
	Martinique, French West Indies			
La p. des Carrieres..	French Marine de Guerre........	HYV	600 2000	....
	Netherlands			
The Hague..........	Velthuyzen....................	PCKK	1050	......
Ijmuiden...........	Middebraad....................	PCMM	1050	......
The Hague..........	Nederlandsche Radio Industri...	PCGG	1050	......
The Hague..........	Laboratorium Heussen..........	PCUU	1050	......
Amsterdam..........	Smith and Hooghout............	PA5	1050	......
Amsterdam..........	Vas Diaz Press Office...........	PCFF	2000	......
Hilversum	Dutch Radio Apparatus Factory.	NSF	1050	......
	New Zealand			
Dunedin............	Otago University...............	4XO	140	......
Auckland...........	Auckland Radio Service.........	1YA	260	200
Auckland...........	C. H. Pearson for Newcombe (Ltd)	1YL	260	500
Wellington.........	Wellington Broadcasters (Ltd.)...	2YB	275	15
Wellington.........	Dominion Radio Co.............	2YK	275	15
Gisborne...........	Gisborne Radio Co.............	2YM	335	500
Dunedin............	British Electrical and Engineering Company....................	4YA	310	500
	Portugal			
Lisbon.............	Aero Lisboa...................	None	370 400	....
	South Africa			
Johannesburg.......	Asso. of Scientific and Tech. Soc..	None	450	......
Cape Horn..........	No data.......................	....	....	......
	Spain			
Madrid.............	No data.......................	EGC	2100	......
Cartagena..........	No data.......................	EBX	1200	......
Madrid.............	No data.......................	PTT	400 700	....
Madrid.............	Radio Iberica..................	....	392	
	Sweden			
Stockholm..........	Royal Telegraph Radio Office....	None	440	500
Stockholm..........	Svenska Radioactiebolaget.......	None	470	300
Goteborg...........	Royal Telegraph Radio Office....	SAB	700	200
Goteborg...........	Ingenior Eliassons..............	SMZX	460	50
Boden..............	Royal Telegraph Radio Office....	SAI	460	50
Gothenburg.........	Nya Varvet....................	....	700	......
	Switzerland			
Lausanne...........	Champ de l' Air................	HB2	1060	......
Geneva.............	Station T. S. F. Cointrin........	HB1	1100	......

ANALYSIS OF RELATED CIRCUITS

In this article we are endeavoring to include the discussion of three of the recent popular circuits. All of these circuits have at least one stage of radio-frequency amplification and a detector. Other tubes may be added to each one if greater amplification is desired. The necessity for such circuits as these is to eliminate the effect which a radio-frequency amplifier gives rise to as it approaches resonance, that is oscillations. Many attempts have been made to prevent oscillations from being set up. Some inventors neutralize the capacity of the tube so that at one frequency feed back through the tube cannot occur. Others introduce reversed tickler coils to produce negative feed back. And still others introduce such losses in the oscillating circuit that the oscillations are damped out.

The Roberts Circuit and the Browning Drake Circuit neutralize the tube capacity, whereas the Superdyne circuit introduces a negative feed back, which just opposes the positive capacity feed back through the tube. This method does not allow the tube circuit to oscillate and yet permits the plate and grid circuits to be tuned to resonance. In the accompanying wiring diagrams we have tried to show all points of similarity between the circuits by arranging them symmetrically and making the connections not common to all stand out above the rest by drawing a heavier line. The following dimensions apply to the four circuits as shown in Fig. 1.

Coils:

L_1 = 50 turns, No. 20 D.S.C.
L_2 = 25 turns, No. 20 D.S.C.
L_3 = 25 turns, No. 20 D.S.C.
L_4 = 50 turns, No. 20 D.S.C.
L_5 = 20 turns, No. 20 D.S.C.

Condensers:

C_1 = 0.0005 mfd., with vernier dial.
C_2 = 0.0005 mfd., with vernier dial.
C_3 = 0.001 mfd., fixed.
C_4 = small neutralizing condensers.
C_5 = 0.00025 grid condenser.

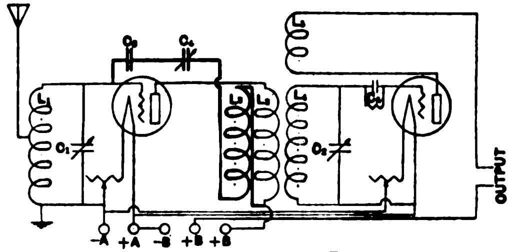
Tubes:

Radio-frequency amplifier UV-201-A, C-301-A, UV-199.
Detector: UV-201-A.

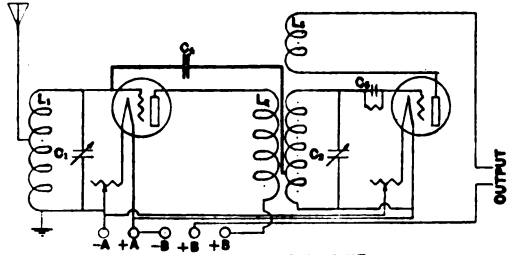
Batteries:

A: According to type of tube used.
B: 90 volts on amplifier; 22.5 volts on detector.

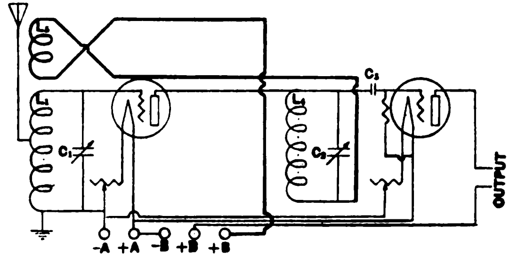
Before attempting to construct any of these circuits, the following features of each should be noted. In the Roberts circuit it is recommended that the coils L_2 and L_3 be superimposed and that all coils be wound on a spider-web form of 5 inches outside diameter, having 13 teeth each 1 7/16 inches long. The A and B batteries



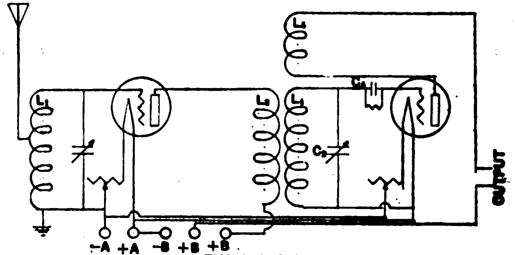
ROBERT'S CIRCUIT.



BROWNING-DRAKE CIRCUIT.



SUPERDYNE CIRCUIT.



TYPICAL CIRCUIT.

Fig. 1

should be shunted by one fixed condenser of 0.0025uf capacity.

In the Browning Drake circuit, L_2 should be wound in a slot or groove cut in a round, wooden disc. 3 inches in diameter. The slot is ⅛ inch wide and ¼ inch deep. L_4 is wound on a 3-inch diameter tube. At one end the wooden disc is fitted tightly against the tube. At the other end a 2-inch tube is mounted to rotate within the 3-inch tube. L_4 is tapped at the fourteenth turn for the neutralizing circuit. See figure 2 for construction diagram.

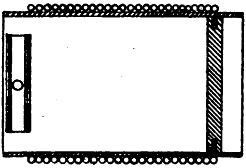


Fig. 2

In the Superdyne circuit, all coils may be spider web or they may be wound on tubes 4 inches in diameter. In this case L_5 is wound on a 3⅝-inch-ball rotor. Of course the experimenter will be able to find other types of coils which will satisfactorily replace those specified above; but there are a few fundamental principles to which he must adhere. Care must be taken to have no parallel grid and plate leads and to keep all of the connections as short as possible. Be sure to have no inductive reaction between the antenna tuning coil and the radio-frequency transformers. In our January, 1924, issue of Radiofax a discussion regarding the operation of the Superdyne type 228 was given.

The last diagram shows the basic circuit which was used as a foundation for the other three. As the circuit stands, it will tend to oscillate and to prevent such action one of several methods may be employed. One of the earlier methods is to insert a high resistance in the grid circuit, such as that offered by a potentiometer. Another method is to make the inductance L_2 very small, say 4 turns instead of 25 turns. This method raises the frequency at which the circuit oscillates above the audible range. Losses may be introduced into the plate circuit by making L_2 of a large number of turns and small diameter. Or again, the coils may be mounted so close to the condensers that a magnetic loss is introduced and the circuit will not oscillate. This method works best when the condensers have metal end plates instead of fibre or bakelite. Capacity coupling may be used by connecting a metallic plate placed near the coil L_4 to the grid of the tube directly. By varying the position of the plate a point will be found where no oscillations occur. The neutralizing methods have already been mentioned in connection with the other three circuits.

The above arrangements can be made to give excellent results. The circuits are noted for clear reception of very weak signals and for their extreme selectivity. On moderate distances a two-tube set will operate a loud speaker fairly well. Good results will only be obtained when the tubes are under the full control of the operator, and this means resonance without any interference from oscillations.

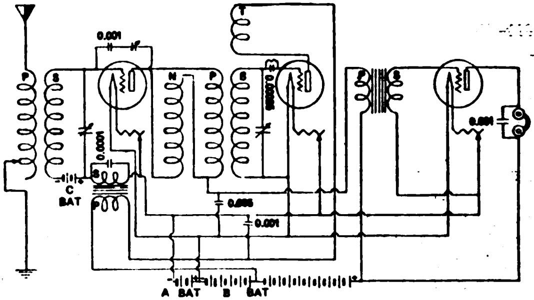


Fig. 3

In Fig. 3 is shown the wiring diagram for the reflexed Roberts circuit. The diagram in Fig. 1 is given as the Roberts circuit to show the similarity between the Roberts method of neutralization and the other methods. The true Roberts circuit, however, is the one given in Fig. 2. The construction details which apply to this figure are given in the table above. In addition to these, we might add that the audio transformers may be of any good type. If the capacity of the reflex transformers is not sufficiently large a 0.001 condenser may be shunted across its secondary terminals. This condenser is not always necessary. If the signals are not very clear, but are of good volume, a variable grid leak should be shunted across the terminals of the audio amplifier transformer.

In all of these circuits it is often advisable to shunt the battery circuits with condensers so as to by-pass radio-frequency and audio-frequency currents. This prevents radio-frequency energy from being picked up in external circuits. The sizes of these condensers may vary from 0.001 mfd. to 0.003 mfd. They can best be determined by trial.

CHAPTER THREE

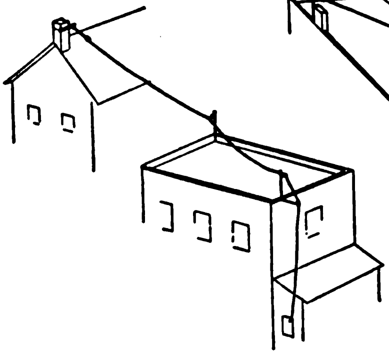
ANTENNAS

Size.—In radio communication it is necessary to have a device for radiating radio waves from the transmitting station and for receiving the radio waves from the air at the receiving station. Such devices are called antennas. Many types of antennas are in general use. The particular location in which the antenna is to be constructed usually goes far to determine its dimensions. The two general classes of antennas are, first, the ordinary elevated wire type usually called simply an "antenna," second, a "coil antenna" (sometimes called a "loop" or "frame aerial") which is usually made by winding a number of turns of wire around a rectangular frame. This latter type is usable indoors. For receiving stations an antenna of the first type is usually the most satisfactory, a good form being a single wire about 75 or 100 feet long and raised 30 to 50 feet above the ground. The higher it is above the ground, the better. The natural wave length of such an antenna is about 200 meters, but the wave length to which the antenna circuit tunes is increased by inserting the inductance coil. The addition of more wires to such a single wire antenna is of but little advantage in securing louder signals. In case the antenna is necessarily shorter than about 75 feet it is desirable to construct it of two wires placed parallel to one another and about 3 feet apart. The wires should be connected together at the distant end and also at the near end. From this latter, near-by, end the "lead-in" wire is brought to the point marked "antenna" on the receiving set.

If necessary, the connection of the lead-in wire may be made to the center of the antenna wires instead of to the end. But this shortens the effective length of the antenna and makes it necessary to add to the series inductance in order to tune to a given wave length, thus somewhat decreasing the strength of the signals.

Figs. 1 to 7 inc. show a number of suggested methods of installing simple antennas. The antenna wires may be strung inside the attic of a house, but care should be taken to locate them as free as possible from proximity to surrounding objects. It is especially desirable to keep the antenna wires some distance from wires used for electric light and power purposes. Antennas

should not be run either under or over electric power lines.



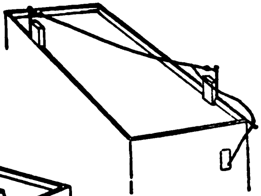


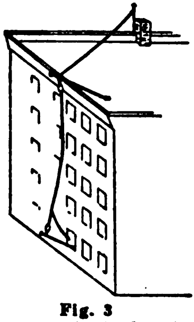
Fig. 1 **Fig. 2**

Fig. 1—A single continuous wire antenna. Where wire passes over edge of roof it is prevented from coming in contact with the building by the insulators at the end of the wood poles.

Fig. 2—A single wire antenna with lead-in held away from edge of building by insulator on end of pole.

For receiving purposes alone it is sometimes satisfactory to use a wire laid near or along the ground though in this case as in the case of the coil antenna, which is described in more detail below, it is necessary to have very sensitive amplifiers in order to receive loud signals from a distant station.

Material.—The usual material for constructing antennas is 7-strand No. 22 hard drawn copper or



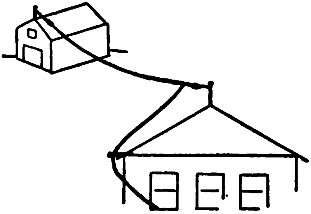


Fig. 3 **Fig. 4**

Fig. 3—A single wire antenna showing how advantage can be taken of the height of a building to get the necessary length. The horizontal length is very short compared to the vertical. The wire is held away from the building by running it through insulators on the end of poles.

Fig. 4—A single wire antenna with lead-in held away from edge of roof.

phosphor bronze wire, though No. 14 or larger bare hard drawn copper is also quite satisfactory. If the antenna is used mainly for receiving signals from long wave stations it is desirable to make it considerably longer than the 75 feet previously mentioned.

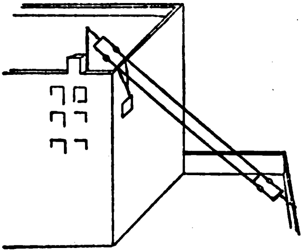


Fig. 5

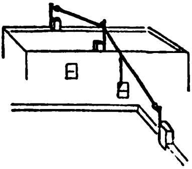


Fig. 6

Fig. 5—A two-wire antenna. The pole on the roof must be sufficiently high or so located that the antenna is held well away from the edge of the roof. This type is not as efficient as one where the entire antenna is above the building.

Fig. 6—A single wire antenna with lead-in taken from the center.

Insulation.—Each end of the antenna should be insulated from its support by means of an insulator. Almost any insulator of glazed porcelain, glass, impregnated wood, or other material which will not absorb moisture and which has a length of several inches will be satisfactory for receiving antennas. Sometimes two or three porcelain cleats are used in series, the farther one being connected to a rope or heavy cord which is run through a pulley for convenience in raising or lowering the antenna. The lead-in wire should be held away from the building and should enter the room where the receiving apparatus is located through a lead-in bushing or insulator. A small hole may be made in a window pane or the wire may be mounted in any way which will insure its not becoming grounded during wet weather. Inside of the house the wiring should be as short and direct as possible and should not run close to the other wires or water pipes except where the ground connection is made. The receiving apparatus should be located as close as convenient to the entrance of the wire into the room.

Ground Connection.—A good ground connection is usually secured by connection to a water pipe or any thoroughly grounded metal structure. Sometimes louder signals may be secured by using several different ground connections together. If, however, one of the ground connections is poor and has a long connecting wire it may reduce the audibility of signals below that obtained with a single connection. It is usually

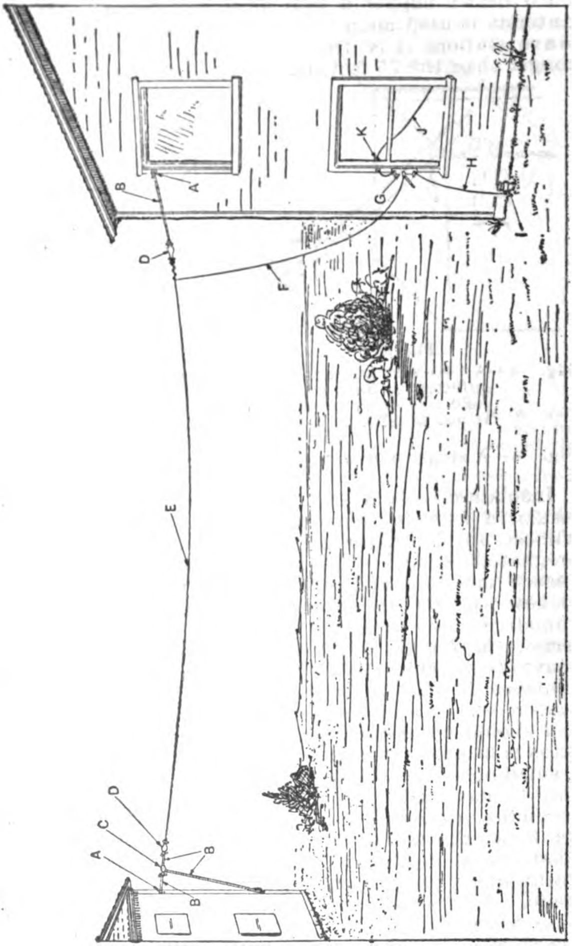


Fig. 7

Fig. 7—Complete detail of single-wire antenna and lead-in: A—screw eye, B—rope, C—pulley, D—insulator, E—antenna, F—lead-in wire, G—lightning switch, H—ground wire, I—ground pipe, J—lead to receiving set, K—insulating tube used where lead-in passes through window frame.

not as satisfactory to use a rod or pipe driven into the ground since the soil surrounding the pipe may become dry and fail to make good connection. To insure good electrical contact with the grounding system, both the pipe and wire connecting to it should be well scraped and the connection made with an approved connecting clamp or else thoroughly soldered. It should be as short as possible.

Protection against Lightning.—The Fire Underwriters' rules require the installation of an approved device for protection against lightning. This should be connected between the antenna lead-in wire and the ground wire at some point very close to the entrance of the antenna to the building. The protective device may be mounted on the receiving set itself if this is located close to the point where the antenna lead-in wire enters the building. While it is not required, it is desirable in receiving sets to employ in addition a single pole double throw knife switch to disconnect the antenna from the receiving set and connect the antenna directly to the ground. This does not obviate the requirement for the protective device which must then be connected so that it will be short circuited by the antenna switch as shown in Fig. 10. It is important that the wires used for the antenna lead-in and for the ground connection be large enough to withstand any danger of mechanical breakage to which they may be subject, while the lead-in wire should be kept from coming in contact with any conducting objects up to the point where it is connected to the receiving set. It is not necessary to insulate the ground wire unless it is an extremely long one. Protective devices, grounding clamps and antenna switches may be purchased from any dealer in radio receiving sets or parts.

Transmitting Antennas.—The most common form of antenna at a radio transmitting station consists of several long parallel horizontal wires with a "lead-in" wire attached to the center or to one end of the horizontal portion. They are called "flat top" antennas, of the "T" or the "inverted L" type. The "fan" or "harp" antenna consists of a number of wires extending upward and spreading somewhat from a common point. A good antenna where tall supporting structures are available is the "cage" antenna, which consists of a number of parallel wires held in a vertical position and separated from one another by spreaders or a barrel hoop. This type can also be used horizontally. None of these forms are superior to the single wire for receiving.

The requirements as to the insulation of antennas used at transmitting stations are more severe on account of the high voltages which are created in the antenna by a transmitting set. The antenna and lead-in wire must be supported at least five inches away from the building

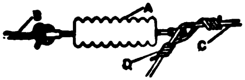


Fig. 8

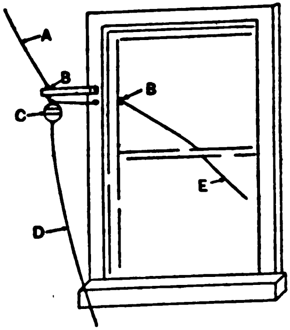


Fig. 9

Fig. 8—Detail at insulator showing how antenna wire may be passed through the eye of the insulator and be secured by a tie wire. A—insulator, B—rope for raising and lowering the antenna, C—antenna wire, D—tie wire. This arrangement allows the use of a continuous wire forming both antenna and lead-in, thus eliminating the necessity for soldered joints.

Fig. 9—Detail showing arrangement of lightning arrester. A—lead-in from antenna, B—insulating tube through board used to hold lead-in away from building and where lead-in passes through window frame, C—lightning arrester, D—ground wire, E—wire to receiving instruments. Care must be taken that no appreciable strain is placed on the binding posts of the lightning arrester.

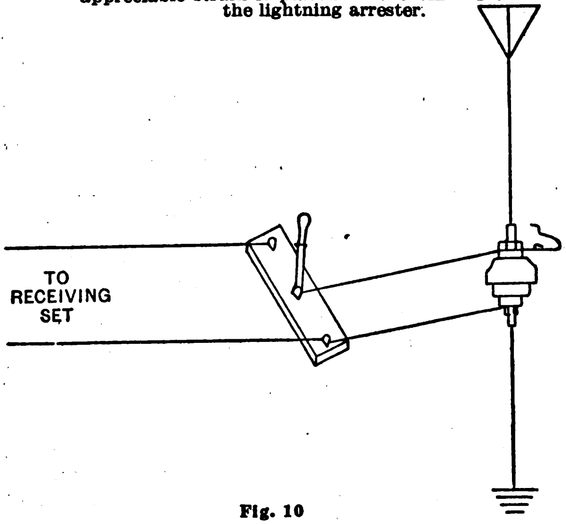


Fig. 10

Fig. 10—Wiring arrangement when using both a lightning switch and a lightning arrester. When lightning switch is thrown to the lower position, thus grounding the antenna, the arrester is short circuited.

wall. The protective device referred to above is not required on transmitting sets, but instead it is necessary to install a grounding switch which will carry a current of 60 amperes and which has a spacing of at least 5 inches between the central contact and either end connection. The wire leading to the ground from this switch need not be insulated but must, as in the case of receiving installations, be thoroughly strong mechanically.

Counterpoise.—Sometimes it is convenient, instead of making a connection through the receiving set to the ground, to replace the ground connection by a wire running to a set of wires which approximately duplicates the antenna. This set of wires is called a counterpoise. This is more commonly used at transmitting stations than at receiving stations. It is often convenient to run the counterpoise wires out in several directions from the radio set, supported a foot or so above the ground and insulated from it. The wires should cover an area at least as large as that covered by the antenna and should be placed below the antenna. Under some conditions of the surroundings of a radio station it is found to be an advantage to connect the transmitting set to both the ground and a counterpoise. When a counterpoise is used, both the antenna and counterpoise wires must be connected to the ground through the approved protective device as a protection against lightning. A counterpoise is especially useful where the ground is very dry or where the receiving set is located in one of the upper floors of a tall building where the distance to the ground is especially great.

Directional Properties.—A long low antenna is somewhat directional in its action, that is, it will receive signals slightly better when the long open end (the end opposite the lead-in connection) is pointed in a direction away from the transmitting station which it is desired to hear. For short antennas, however, this effect is not very noticeable and it makes little difference in which direction the antenna is strung. For further information regarding the directional and other properties of antennas, as well as suggestions for the construction of antennas and counterpoises of different types, the reader is referred to the book "The Principles Underlying Radio Communication.*"

Coil Antennas.—A compact and sometimes very satisfactory type of antenna is the coil antenna which consists of a few turns of wire wound on a wooden frame about four feet square. No ground connection is required on an antenna of this type. Arrangements of such an antenna are shown in Figs. 11, 12 and 13.

*The "Principles Underlying Radio Communication" is published as Signal Corps Radio Communication Pamphlet No 40, prepared by the U. S. Bureau of Standards. It may be purchased from the Supt. of Documents, Government Printing Office, Washington, D. C., for $1.00.

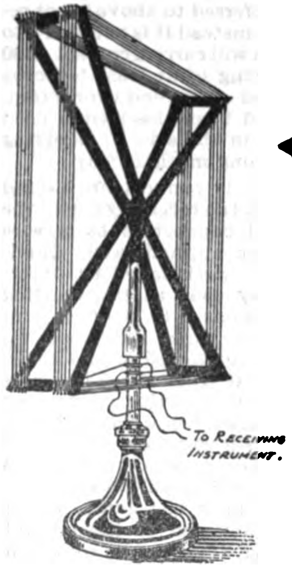


Fig. 11

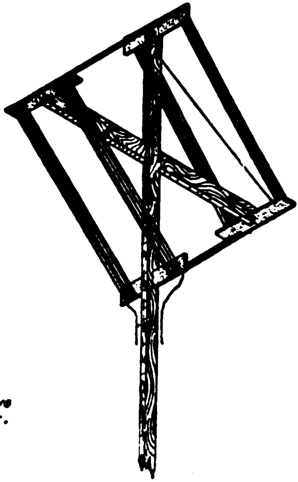


Fig. 12

Fig. 11—Coil antenna mounted on pedestal and arranged to allow revolving coil around its vertical axis.

Fig. 12—Coil antenna on wood frame fitted with end pieces of sheet insulation such as bakelite or hard rubber. To be mounted so that coil can be revolved. The two ends of the coil shown hanging at side of support are to be connected to the receiving instruments.

On account of the small size of this antenna it cannot be used satisfactory for receiving very distant stations unless sensitive amplifiers are employed with it. However, for nearby stations or where good amplification is available the coil antenna has many advantages. One of the most important of these is its directional characteristic. When the coil is turned so that its plane is in the line of direction toward the transmitting station the loudest signals are received. When the coil is turned at right angles to this direction either no signals or only weak signals are received. This makes it possible to receive messages from some stations while avoiding the reception of messages from others even though the stations are transmitting on the same wave length.

Circuits for Coil Antenna.—For receiving from nearby stations on a coil antenna it is desirable to have an electron tube detector and two stages of audio frequency amplification. For receiving from stations 50 or 100 miles away it is advisable to employ five or six stages of

amplification. The above statements refer chiefly to the reception from transmitting stations, such as are ordinarily used for radio telephone broadcasting.

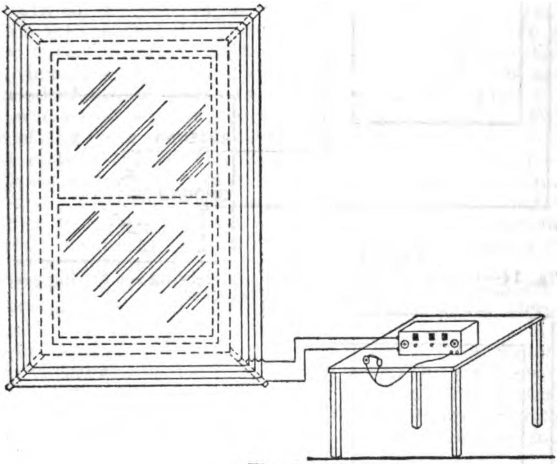


Fig. 13

Fig. 13—A coil antenna made by wrapping a length of wire around a window. The wire is held in place by being forced into saw kerfs in pieces of sheet insulation placed at each corner as shown. This type is of course fixed in position and full advantage of the directional quality of coils can not be obtained.

However, if coils are wound with a large number of turns of wire they can be used even with only moderate amplification to receive signals from European stations. A coil antenna may be connected to an ordinary receiving set. The actual connection which is used depends upon the wiring of the inside of the receiving set. If the receiving set or tuner has a series condenser the coil antenna may simply have its two terminal wires connected to the antenna and ground binding posts of the receiving set as shown in Fig. 14. If the receiving set or tuner does not have a series condenser it is necessary to connect a variable condenser in series with one side of the coil antenna, between it and the ground terminal of the tuner. The other terminal of the coil is connected to the antenna binding post of the tuner. This connection is shown in Fig. 15. It is very simple to use the coil antenna and an extra variable air condenser in place of the regular tuner. In this case the condenser is connected across the terminals of the coil and these two terminals are also connected to the grid and filament terminals of the detector or radio-frequency amplifier which is used. This circuit is very simple as may be seen by reference to Fig. 16.

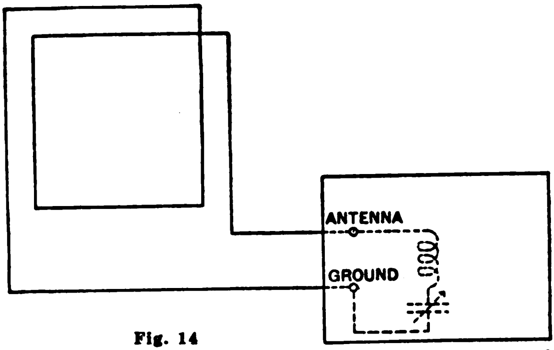


Fig. 14

Fig. 14—Coil antenna connected to receiving set having series coil and condenser

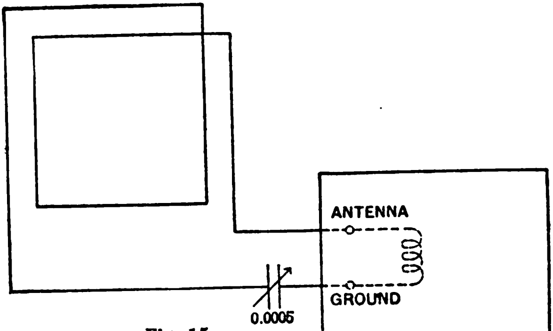


Fig. 15

Fig. 15—Coil antenna and tuning condenser connected to receiving set having series coil only.

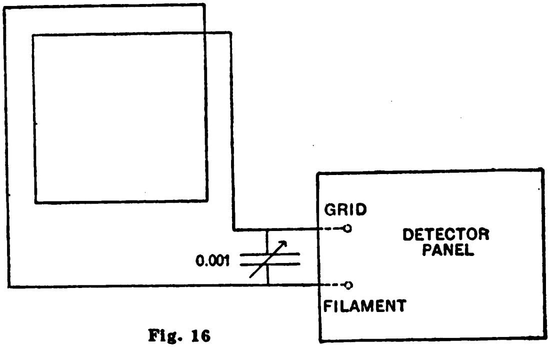


Fig. 16

Fig. 16—Coil antenna and variable condenser connected to detector panel.

Construction of Coil Antennas.—In constructing a coil antenna for receiving, it is desirable to use as many turns of wire as possible without exceeding the wave length of the station to which it is desired to listen. This means that for short waves one can use only a few turns of wire while for long waves a large number of turns may be wound on a frame. Square coils are usually found most convenient to construct. Figs. 14, 15 and 16 show a number of types of coil antennas. For receiving from the ordinary radio telephone broadcasting stations it is convenient to use a coil about four feet square wound with four turns of wire spaced ½ inch apart. The following table gives the wave length range to which the coil antenna receiving set can be tuned, assuming several different numbers of turns of wire wound on a frame 5 feet square.

Using variable condenser having maximum capacity 0.00065 microfarad. Minimum capacity 0.00004 microfarad.

Four turns	200 to 400 meters
Eight turns	350 to 700 meters
Sixteen turns	500 to 1000 meters

Using variable condenser having maximum capacity 0.0014 microfarad. Minimum capacity .000004 microfarad.

Four turns	375 to 650 meters
Eight turns	400 to 950 meters
Sixteen turns	675 to 2300 meters

CALCULATIONS FOR A SINGLE-WIRE ANTENNA

In the October Radiofax, tables and curves were presented whereby the experimenter is enabled to determine easily the inductance and capacity of the antenna system, and formulas given for applying these values to the problem of determining the resonance frequency and wave-length of the antenna.

The following nomenclature is used:

C_o = loading capacity

L_o = loading inductance

C_h = capacity of horizontal portion

C_v = capacity of vertical portion

L_h = inductance of horizontal portion

L_v = inductance of vertical portion

l_h = length of horizontal part, feet

l_v = length of vertical part, feet

l_a = Total length, feet

In this article we are presenting means for arriving at the values of the resonance frequency and wave-length with very little work. The method is as follows:

Assuming the curves in Figs. 1 and 3 of the October article on antennas to be straight lines, they may be approximately represented by the equations

$$C_h = 1.8\ l_h \times 10^{-6}\ \mu f \text{ and } L_h = 0.7\ l_a\ \mu h$$

except for very low antennas. Adding these to the approximate equations for C_v and L_v in the October article,

$$C_a = (1.8\ l_h + 1.5\ l_v + 12) \times 10^{-6}\ \mu f$$
$$L_a = (0.7\ l_h + 0.65\ l_v - 4.6) \times 1/3\ \mu h$$
$$= 0.23\ l_h + 0.22\ l_v - 1.5\ \mu h$$

Note the use of the factor 3, explained on p. 13 of the October article. For rough calculations very little error is introduced by replacing these equations by $C_a = 1.8\ l_a \times 10^{-6}$ and $L_a = 0.23\ l_a$. From this

$$f = \frac{159.3}{\sqrt{L_a C_a}} = \frac{247{,}000}{l_a} \text{ or } \lambda = 1.22\ l_a,$$

in which f is the fundamental frequency of the unloaded antenna, in kilocycles per second, l_a is in feet, and λ, the wave-length, is in meters.

Loaded Antenna:—

From the tables in the October article determine the values of C_h, C_v, L_h, and L_v. If a single layer loading coil is used in series with the antenna, its inductance may be obtained from the table in September Radiofax in the article on "Self-Inductance of Single Layer Coils." This is denoted by L_o. If any other type of loading inductance is used, its value may be obtained from the manufacturers' tables or from articles which are to come in Radiofax. L_o also includes the self and mutual inductance of any coupling apparatus that may be placed in the antenna system. In other words, L_o is the sum of all concentrated inductances in the antenna circuit.

The calculation of the inductance values of variometers, variocouplers, and other forms of couplers is very complicated, but as a first approximation we may assume the following as representative of the average variometer and variocoupler used in receiving broadcast messages and concerts:

Mutual inductance.................250 microhenries
Self-inductance, rotor and stator, each: 415 microhenries

These are maximum values; that is, values obtained when the axes of the coils coincide.

The capacity, C_s, of condensers in series with the antenna may be calculated from formulas appearing in the August Radiofax, or from manufacturers' tables. The only work that the experimenter has to do then is perform the following simple operations:

$C_a = (C_h + C_v) \div 1{,}000{,}000$ $\qquad$ $L_a = (L_h + L_v) \div 3$

$C = \dfrac{C_a C_s}{C_a + C_s}$ for series condenser $\qquad$ $L = L_a + L_s$, for series inductance

in which C_h and C_v are in micro-microfarads, C_s, C_a and C in microfarads and all inductances in microhenries. C_a and L_a are the total capacity and inductance of the unloaded antenna and ground lead.

C and L are the total effective capacity and inductance of the antenna system. Then simply multiply C and L together and look for the corresponding fundamental frequency and wave-length in the table below.

If there is no loading capacity, then C is simply C_a; if there is no loading inductance, then L is simply L_a.

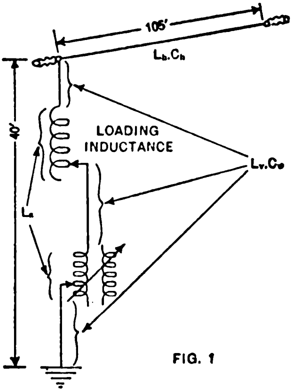


FIG. 1

As an example of the application of this method of antenna calculation take the case illustrated in Figure 1. This is a singe-wire antenna 105 feet long having a mean height of 40 feet from the ground. Tuning is accomplished by means of the variocoupler and the series loading coil, which, for convenience, is of the single layer type. Let us determine the fundamental frequency and wave-length of this outfit.

From the tables in the October Radiofax,

L_h = 75 microhenries $\qquad$ C_h = 183 micro-microfarads
L_v = 25 microhenries $\qquad$ C_v = 73 micro-microfarads

The length of the loading coil is $5 \times 2.54 = 12.70$ cms., and the diameter is $4 \times 2.54 = 10.16$ cms. For an approximate value take the length as equal to

$12\frac{3}{4}$ cms. and the diameter as equal to 10 cms. The value of the inductance, as shown in the table in September Radiofax, lies between 1965 and 2382 microhenries. Interpolating, the correct value is 2110 μh.

We have stated an average value of the self-inductance of the stator of a variocoupler to be about 415 microhenries. The mutual inductance can be neglected, as will be explained below. The total lumped inductance in the antenna system is then

$$L_s = 2110 + 415 = 2525\ \mu h.$$

Then

$C_a = (C_h + C_v) \div 1{,}000{,}000 = (183 + 73) \div 1{,}000{,}000 = 0.000256\ \mu f.$

$L_a = (L_h + L_v) \div 3 = (75 + 25) \div 3 = 33\ \mu h.$

$L = L_a + L_s = 33 + 2525 = 2558\ \mu h.$

$L \times C_a = 2558 \times 0.000256 = 0.656.$

In the table the values corresponding to 0.656 are

$\lambda = 1525$ meters $f = 197$ kilocycles per second.

If the loading coil is omitted, the values are

$L \times C_a = 0.179$ $\lambda = 800$ meters $f = 375$ kilocycles.

If the variocoupler is also removed, the natural frequency of the antenna alone is

$L \times C_a = 0.00845$ $\lambda = 175$ meters $f = 1720$ kilocycles.

These values are inclined to be a little low, due to the fact that some constants, as for instance, the capacity of the coils, have not been taken into account. For most practical purposes the results will be fairly accurate, and will agree closely with results obtained by measurement.

The range of the set is determined by taking the difference between the values of wave-length or frequency when maximum and minimum inductance and capacity in the circuit are in use. The lower limit of wave-length is secured when the loading coil is cut out.

L_s then equals simply 415 mh.

$L = 33 + 415 = 448$ mh.

$L \times C_a = 448 \times 0.000256 = 0.072.$

The corresponding wave-length and frequency are $\lambda = 505$ meters and $f = 594$ kilocycles per second.

The range is then from about 500 meters to 1500, or 600 kilocycles to 200.

The same general method is used for the case of a loading capacity such as a condenser in series with the variocoupler.

The reason why the mutual inductance can be neglected in these calculations will now be explained. In the first place, loose coupling is desirable because the attainment of selectivity depends upon it. With an outfit such as described above, loose coupling is necessarily attained, pretty much regardless of the setting of the variocoupler. This apparent paradox results from the fact that coupling is a function of the total inductance in the circuits and not simply that in the

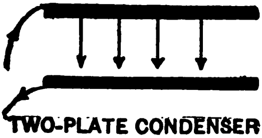
coupling coils. The coeffic. of coupling is $M / \sqrt{L_1 L_2}$ where M is mutual inductance and L_1 and L_2 are total self-inuctances in primary and secondary circuits respectively. In a case such as here considered, the coefficient of coupling would be small and the coupling would thus be loose, for all settings of the variocoupler, and the mutual inductance can thus be neglected in rough calculations of the range of the set.

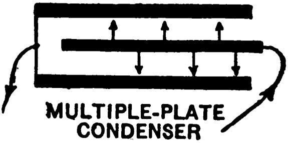
Meters	Kilo-cycles	L × C	Meters	Kilo-cycles	L × C	Meters	Kilo-cycles	L × C
100	3,000	0.00282	550	546	0.0852	800	375	0.1801
110	2,727	0.00341	555	541	0.0867	805	373	0.1824
120	2,500	0.00405	560	536	0.0883	810	370	0.1847
130	2,308	0.00476	565	531	0.0899	815	368	0.1870
140	2,143	0.00552	570	527	0.0915	820	366	0.1893
150	2,000	0.00633	575	522	0.0931	825	364	0.1916
160	1,875	0.00721	580	517	0.0947	830	361	0.1939
170	1,764	0.00813	585	513	0.0963	835	359	0.1962
180	1,667	0.00912	590	509	0.0980	840	357	0.1986
190	1,579	0.01015	595	504	0.0996	845	355	0.201
200	1,500	0.01126	600	500	0.1013	850	353	0.203
210	1,429	0.01241	605	496	0.1030	855	351	0.206
220	1,364	0.01362	610	492	0.1047	860	349	0.208
230	1,304	0.01489	615	488	0.0165	865	347	0.211
240	1,250	0.01621	620	484	0.1082	870	345	0.213
250	1,200	0.01759	625	480	0.1100	875	343	0.216
260	1,154	0.01903	630	476	0.1117	880	341	0.218
270	1,111	0.0205	635	472	0.1135	885	339	0.220
280	1,071	0.0221	640	469	0.1153	890	337	0.223
290	1,034	0.0237	645	465	0.1171	895	335	0.225
300	1,000	0.0253	650	462	0.1189	900	333	0.228
310	968	0.0270	655	458	0.1208	905	331	0.231
320	938	0.0288	660	455	0.1226	910	330	0.233
330	909	0.0306	665	451	0.1245	915	328	0.236
340	883	0.0325	670	448	0.1264	920	326	0.238
350	857	0.0345	675	444	0.1283	925	324	0.241
360	834	0.0365	680	441	0.1302	930	323	0.243
370	811	0.0385	685	438	0.1321	935	321	0.246
380	790	0.0406	690	435	0.1340	940	319	0.249
390	769	0.0428	695	432	0.1360	945	317	0.251
400	750	0.0450	700	429	0.1379	950	316	0.254
410	732	0.0473	705	426	0.1399	955	314	0.257
420	715	0.0496	710	423	0.1419	960	313	0.259
430	698	0.0520	715	420	0.1439	965	311	0.262
440	682	0.0545	720	417	0.1459	970	309	0.265
450	667	0.0570	725	414	0.1479	975	308	0.268
460	652	0.0596	730	411	0.1500	980	306	0.270
470	639	0.0622	735	408	0.1521	985	305	0.273
480	625	0.0649	740	405	0.1541	990	303	0.276
490	612	0.0676	745	403	0.1562	995	302	0.279
500	600	0.0704	750	400	0.1583	1,000	300	0.282
505	594	0.0718	755	397	0.1604	1,100	272	0.341
510	588	0.0732	760	395	0.1626	1,200	250	0.405
515	583	0.0747	765	392	0.1647	1,300	230	0.476
520	577	0.0761	770	390	0.1669	1,400	214	0.552
525	572	0.0776	775	387	0.1690	1,500	200	0.633
530	566	0.0791	780	385	0.1712	1,600	187	0.721
535	561	0.0806	785	382	0.1734	1,700	176	0.813
540	556	0.0821	790	380	0.1756	1,800	166	0.912
545	551	0.0836	795	377	0.1779	1,900	157	1.015

CONDENSER ANTENNAS

A "condenser antenna" is defined by the Institute of Radio Engineers as the same thing as an "open antenna," namely, an antenna consisting of two capacity areas. Such a definition is necessary to distinguish from the coil antenna or loop antenna, which is quite a different thing. The more common types of condenser antennas are the usual antennas having elevated wires for the upper capacity area and either a counterpoise or the ground for the lower capacity area. A special type, in which both capacity areas consist of wires or metal plates, both elevated well away from the ground, is sometimes meant when the term "condenser antenna" is used. This "plate condenser antenna" will be dealt with below after some general qualities of condenser antennas are mentioned.

A condenser antenna is primarily a condenser. It is simply the condenser of a radio circuit made large enough to have an appreciable power intercharge with the ether, so that it either radiates or absorbs radio wave power. Any 2-plate condenser of large physical dimensions will do; this statement is quite important. In the first place, it must be large; hence the ordinary antenna wire is strung high above the ground. In the second place, it must be a 2-plate and not a multiple-plate condenser. The reason for this may readily be seen from the diagrams. In the 2-plate condenser, the





instantaneous "displacement" current in the space between the plates has a certain direction. In a 3-plate condenser, as shown, the displacement current in one space is opposite in direction to that in the other space between plates. The effects at a distance neutralize each other. This is true, wholly or in part, for any condenser of more than two plates.

At least one of the two plates must be more or less parallel to the ground, or their principal effect will be to transmit the wave into the ground, or, in reception, to be unaffected by the incoming wave. The antenna's effectiveness in either transmitting or receiving depends on the vertical separation of the two plates. An effort is therefore made to raise the upper condenser plate to a considerable height. For reception, however, this is not so important, because a low and relatively

ineffective antenna can be compensated by amplification. For this reason small antennas can be used for reception. The use of a wire hung up in the ordinary room is familiar, the lower condenser plate in that case being a mass of metal, such as the house piping.

A genuine "plate condenser antenna" has some advantages in those circumstances where a low or small antenna is possible. It may consist of two horizontal spreads of one or more square yards of galvanized or copper screening, netting, or sheet, with a vertical separation of 6 inches to 6 feet. Another form is simply two horizontal copper wires about 20 feet long, with a vertical separation of a few feet. No object should be allowed to be closer to the edges of the plate condenser antenna than the distance between the two "plates." One of the great advantages of such an antenna lies in this elimination of all objects from the space between the plates. Other forms of open antennas have a great variety of objects instead of merely the ideal (air) between the plates, and such objects are the cause of power loss that diminishes the signal strength. When used outdoors, the lower plate of the plate condenser antenna should have considerably more spread than the upper plate, so that the effect is confined to the air between the plates instead of spreading around the edges and possibly to ground.

An advantage of small antennas, such as the plate condenser antennas here described, is the relative freedom from atmospheric disturbances. As a rough rule, the troubles from atmospheric disturbances are proportional to the largest dimension of the antenna.

It should be borne in mind that what we here call a "plate condenser antenna" is a complete condenser consisting of two plates. Both of these plates are well away from the ground. In the more ordinary types of open antennas, the lower plate (counterpoise) may be close to or on the ground, or may even be the ground. As to the question how high above the ground a plate condenser should be placed, it is desirable to have the lower plate at a height above the ground greater than the distance between the plates. When used indoors, it is desirable to maintain the upper plate also at a distance from the ceiling or other objects greater than the distance between the plates.

As to the signal intensity obtainable with a small plate condenser antenna as described, for the broadcasting frequencies the received signals are of about the same loudness as with a coil antenna of the same general dimensions. It is better than the coil antenna for the higher broadcasting and the amateur frequencies.

Photographs of experimental plate condensers used in experiments at the Bureau of Standards were given on pages 29 and 30 of October Radiofax.

CAPACITY OF TWO-WIRE ANTENNAS

In articles previous to this we have presented to the reader constants of the single-wire antenna and methods of using them. In this article we present a table of capacities of two-wire antennas. Tables of inductances will follow in the next issue.

The table is given below, and Figure 1 has been plotted from it. These curves have been constructed for the purpose of analysis, that is, of determining the effect of the added wire in the antenna and the most economical dimensions.

Capacity of Horizontal Portion of 2-Wire Antennas (Micro-microfarads)

(All Lengths in Feet)

Hght (Feet)	Length (Feet)							
	15	30	45	60	75	90	105	115
	Spacing 1 Foot							
20	43.2	78.3	113.5	147.5	182.2	217.0	252.0	276.0
40	41.8	76.2	108.4	140.4	171.7	203.0	234.0	255.0
60	41.8	75.3	107.0	138.0	168.0	198.7	228.0	248.5
80	41.8	74.8	106.0	136.5	166.5	195.5	224.5	244.0
100	41.8	74.8	105.6	136.0	165.6	194.3	222.5	243.0
120	41.7	74.6	105.5	135.5	164.0	193.5	221.5	240.5
	Spacing 2 Feet							
20	46.1	83.4	120.2	156.6	192.6	229.0	267.0	291.0
40	45.2	80.8	114.7	148.0	181.5	214.0	246.0	268.0
60	44.8	79.8	113.3	145.6	177.7	208.0	240.5	261.0
80	44.7	79.3	112.5	144.2	176.5	206.0	236.0	256.5
100	44.6	79.3	111.6	143.2	174.0	204.0	234.0	254.0
120	44.5	79.2	111.4	142.6	173.0	203.0	233.0	252.0
	Spacing 3 Feet							
20	47.8	86.7	124.2	162.0	200.0	237.0	275.0	301.0
40	47.0	83.7	119.0	153.0	187.5	221.1	254.0	277.0
60	46.7	82.8	117.0	150.0	183.0	215.0	248.0	269.0
80	46.6	82.1	115.8	148.7	180.6	212.5	243.5	264.5
100	46.5	82.0	115.5	148.2	180.0	210.5	241.5	261.0
120	46.4	81.8	115.0	147.5	179.2	209.5	239.0	260.0
	Spacing 4 Feet							
20	49.3	88.5	127.8	166.0	204.5	243.0	283.0	308.0
40	48.2	86.2	122.0	157.2	191.2	227.0	261.0	284.0
60	48.1	84.9	120.2	153.5	187.5	221.0	253.0	275.0
80	47.9	84.3	119.2	152.3	185.5	217.0	249.0	270.0
100	47.8	84.2	118.4	151.2	183.6	215.0	247.0	268.0
120	47.7	84.0	118.0	150.5	182.0	213.5	246.0	266.0
	Spacing 5 Feet							
20	50.6	90.9	130.5	169.5	209.0	248.0	288.0	314.0
40	49.5	87.9	124.3	160.0	195.7	230.5	264.5	289.0
60	49.2	86.8	122.3	157.0	190.5	225.0	257.0	280.0
80	49.0	86.1	121.5	155.3	188.4	220.5	253.0	275.0
100	48.9	86.0	120.6	154.0	187.5	219.0	251.0	271.5
120	48.8	85.9	120.0	153.5	186.0	218.0	249.0	270.5

The separate groups of curves in Figure 1 are for various lengths of antenna, each group being composed of curves for the different spacings of the two wires. It will be noticed that the curves are for the most part horizontal, that is, changes in the height of the antenna above about thirty or forty feet produce almost imperceptible changes in the capacity of the antenna. This is about where the bends of the curves occur. There-

fore, as a first conclusion we may say, as for the single-wire antenna, that it does not pay to build a two-wire antenna higher than about 35 feet for any reason other than to avoid proximity with neighboring buildings, etc.

In each group it will be seen that the effect of increasing the spacing of the wires from 4 to 5 feet is less than the effect of increasing the spacing from 1 to 2 feet. Thus although the capacity may be increased by increasing the spacing, there is a limit to the spacing beyond which it does not pay to go, as the gain in capacity will be small compensation for the added difficulties of construction and increased cost.

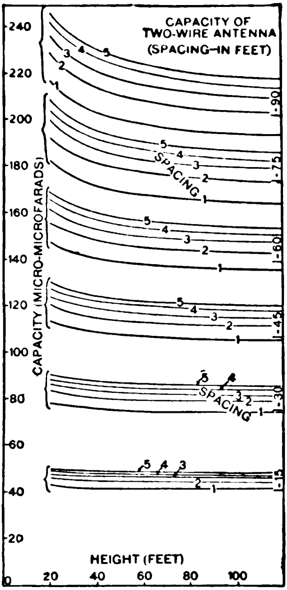


Fig. 1

Figure 2 illustrates this point more clearly. Since height has small effect on the capacity of the antenna, the effect of height has been neglected in these curves for the purpose of avoiding confusion, and each curve in Figure 2 may be understood to represent a pencil of curves for different heights, each pencil for a different length, of which the ones shown are average curves. The knees of these curves occur at a spacing of about 1 foot. For spacings less than this the capacity decreases considerably, and we lose the very effect we wish to gain by using the extra wire. Thus, when the spacing between the wires become zero, that is, when the wires coincide, we have the capacity of a single-wire antenna, given by the points on the vertical axis of coordinates.

Beyond the 1-foot spacing the capacity increases indefinitely, but the increases are gradual, so that it does not pay to go beyond, say, a 2-foot spacing. We say 2 feet rather than 1, since constructional difficulties do not occur at this spacing, and we wish to obtain as much capacity as possible for a given length of antenna. It will be noticed that the slopes of the curves are greater for the greater lengths. This means that we may use greater spacings for the greater lengths. For amateur and broadcast receiving antennas, however, we may consider a spacing of about 2 feet as representing good practice.

We may now summarize our analysis as follows: The capacity of a two-wire antenna may be increased by

(1) Decreasing the height. This effect is very small and may in general be neglected, providing the height is greater than about 35 feet and the antenna is sufficiently removed from neighboring buildings, etc. It does not pay to exceed this height except for this reason.

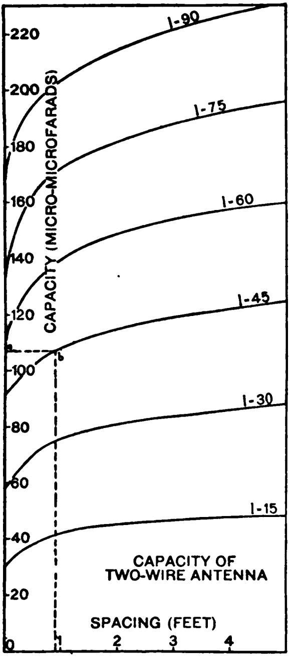


Fig. 2

(2) Increasing the length. This is the most important factor to consider in changing the capacity of the antenna.

(3) Increasing the spacing. The increases in capacity become less and less as the spacing is increased so that it does not pay to go beyond a 2-foot spacing for amateur and broadcasting wave-lengths.

In determining the wave-length of an antenna the capacity is the most important factor, since the inductance of the antenna is generally very small compared to the inductance in the tuning apparatus connected with it. In many cases, where the calculations need only be approximate, the inductance of the antenna may be entirely neglected, the inductance of the antenna circuit being taken as equal to the inductance of the tuning coils connected with it. However, to be technically correct the inductance should be taken into account.

The design of small antennas for reception is comparatively simple. The method was given in the November Radiofax in detail, but for convenience we repeat here the formulas used:

The capacity of the antenna alone is

$$C_a = C_h + C_v,$$

in which C_h and C_v are the capacities of the horizontal and vertical portions of the antenna. They are all in micro-microfarads, and should be converted to microfarads by dividing by 1,000,000. For the single-wire antenna C_h is obtained from the table in the October Radiofax, p. 11, and C_v in the same issue, p. 12, Fig. 2.

For the two-wire antenna, C_h is obtained from the table below, and C_v from Fig. 2, p. 12, of the October Radiofax.

If no series condenser is used, the total capacity of the antenna circuit, C, is the same as C_a, above, or, $C = C_a$. If a series condenser is used, the total capacity of the antenna circuit is

$$C = \frac{C_a C_s}{C_a + C_s}$$

This latter calculation can be eliminated, however, by the use of a chart which will soon appear in Radiofax. In the meantime the student may perform the calculation himself.

The inductance of the antenna alone is

$$L_a = (L_h + L_v) \div 3,$$

in which L_h and L_v are the inductances of the horizontal and vertical portions of the antenna respectively. All these quantities are in microhenries. To obtain the total inductance in the antenna circuit, any inductance which is placed in series with the lead-in wire must be added to this, or,

$$L = L_a + L_s,$$

in which L_s is the added series inductance. Values of L_h for a single-wire antenna are given in Radiofax, October, p. 13, Table 2, and for L_v on the same page, Figure 4. L_h for two-wire antennas will be given in the next issue of Radiofax.

Having determined C and L, multiply them together to obtain the oscillation constant CL (C in microfarads and L in microhenries), and find the wave-length or frequency corresponding to this in the table in the November Radiofax, p. 36. L_s for single-layer coils may be found in the table in the September Radiofax, pp. 25 and 26.

Some interesting points may be brought out by a study of these charts. Thus, in Figure 2 the point a gives the capacity of a single-wire antenna 60 feet long. As indicated by the broken line a b, the same capacity may be obtained by using a two-wire antenna 45 feet long, having the wires spaced 9/10 of a foot apart, or approximately 1 foot. We have said above that increasing the separation between the wires increases the capacity. The limit to this is obtained when the separation is so great that neither wire has any effect on the other. The maximum capacity thus obtained is slightly less than twice the capacity of the single wire.

These tables apply accurately only to horizontal antennas, the wires being connected together at both ends. Nothing can be gained by connecting the wires in any other manner, as by doing so, although we will increase the inductance of the antenna slightly, the capacity will be decreased considerably. In antennas the main factor is the capacity, in loops the inductance.

INDUCTANCE OF TWO-WIRE ANTENNAS

In keeping with our intention to furnish the readers of Radiofax with technical material in such form that they may be able to use it, we present in this article tables of inductances of two-wire antennas, with a discussion of the factors that enter into these quantities. This follows the article on Capacity of Two-Wire Antennas, presented in the February issue.

Table 1 below gives the mutual inductance existing between two horizontal grounded wires parallel to each other. In determining the inductance of antennas of more than one wire, the following formula is to be used:

$$L_h = \frac{L'_h + (n-1)M}{n} - kl,$$

in which the subscript h refers to the horizontal portion of the antenna only, L'_h is the self-inductance of one of

TABLE 1
Mutual Inductance of Two Parallel Grounded Wires (Microhenries)
(All lengths in Feet)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
20	2.1	5.0	8.2	11.6	14.8	18.0	21.5	23.7
40	2.2	5.4	8.9	12.5	16.4	20.4	24.3	27.0
60	2.2	5.5	9.1	12.9	17.2	21.0	25.2	28.0
80	2.2	5.5	9.2	13.2	17.3	21.5	25.8	28.8
100	2.2	5.6	9.3	13.3	17.6	21.8	26.2	29.1
120	2.2	5.6	9.4	13.4	17.7	21.9	26.5	29.5
	Spacing 2 Feet							
20	1.5	3.8	6.4	9.2	11.7	14.4	17.1	18.9
40	1.6	4.2	7.0	10.1	13.2	16.4	19.7	21.8
60	1.6	4.3	7.3	10.5	14.1	17.3	20.9	23.3
80	1.6	4.3	7.4	10.7	14.2	17.8	21.5	24.0
100	1.6	4.4	7.5	10.9	14.4	18.1	21.9	24.5
120	1.7	4.4	7.5	10.9	14.5	18.3	22.2	24.7
	Spacing 3 Feet							
20	1.2	3.2	5.3	7.7	9.9	12.2	14.5	16.1
40	1.3	3.5	6.0	8.7	11.4	14.3	17.2	19.1
60	1.3	3.6	6.3	9.1	12.3	15.2	18.3	20.4
80	1.3	3.7	6.4	9.3	12.4	15.7	18.9	21.2
100	1.3	3.7	6.5	9.5	12.6	16.0	19.3	21.6
120	1.3	3.7	6.5	9.5	12.7	16.1	19.6	21.9
	Spacing 4 Feet							
20	1.0	3.0	4.9	6.7	8.6	10.7	12.7	14.1
40	1.1	3.0	5.3	7.7	10.2	12.7	15.4	17.1
60	1.1	3.1	5.5	8.1	11.1	13.7	16.5	18.5
80	1.1	3.2	5.6	8.3	11.2	14.1	17.1	19.2
100	1.1	3.2	5.7	8.5	11.4	14.4	17.5	19.7
120	1.1	3.3	5.8	8.5	11.5	14.6	17.8	20.0
	Spacing 5 Feet							
20	0.8	2.4	4.1	6.0	7.7	9.5	11.4	12.6
40	0.9	2.7	4.7	7.0	9.2	11.6	14.0	15.6
60	0.9	2.8	5.0	7.4	10.1	12.5	15.2	17.0
80	0.9	2.9	5.1	7.6	10.2	12.9	15.8	17.7
100	1.0	2.9	5.2	7.7	10.4	13.3	16.2	18.2
120	1.0	2.9	5.2	7.8	10.5	13.4	16.4	18.5

the wires, M is the mutual inductance between any two adjacent wires, all in microhenries, l is the length of the antenna in feet, n is the number of wires and k is a constant depending upon the number of wires, n. L'_h is given in Table 2, page 13, of the October Radiofax; M is given in Table 1 above, and k in Table 2 below.

It is to be noticed that if n equals 2, that is, if we are making the calculations for a two-wire antenna, the above formula reduces to

$$L_h = \frac{L'_h + M}{2}$$

TABLE 2

n	k
2	.0
3	.009
4	.019
5	.028
6	.036
7	.044
8	.051
9	.057
10	.062

since k is equal to zero (Table 2). For the convenience of our readers, few of whom use receiving antennas consisting of more than two wires, we have calculated Table 3 from this formula. Table 3, then, gives the inductance of two-wire antennas (horizontal portion only).

Figure 1 has been plotted from Table 3. Many interesting points can be obtained from a study of these curves. In the first place it will be seen that height has very little effect upon the inductance, as also upon the capacity, as shown in the previous issue. The curves are nearly horizontal for the greater part until the height decreases to about 30 or 35 feet. Below this changes in height cause perceptible changes in the inductance.

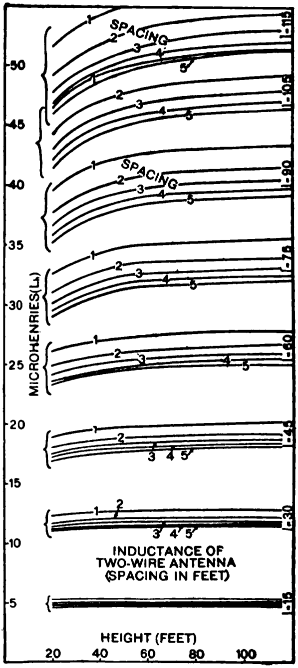


Fig. 1

It will be seen that the chart is divided into groups, each group for a different length of antenna, and consisting of five curves for the five different spacings given in the table. The distance between curves representing spacings of 1 and 2 feet is greater than that between the curves representing spacings of 4 and 5 feet. We thus come to the conclusion that the

inductance decreases as the spacing is increased, and that it decreases rapidly at first as we separate the wires and more slowly as the wires are further and further removed from each other. This point is brought out more clearly in Figure 2.

Since height has little effect upon the inductance, we have eliminated the height from consideration by averaging the inductances in Table 3 for various heights, keeping the length constant for each curve. This gives the curves drawn in solid lines in Figure 2, which are nearly horizontal for the most part, except for the longer lengths of antenna. The greatest variation in inductance is for the smaller spacings.

If we imagine the two wires to be brought so close together that they coincide, we have, for zero spacing, the inductance of a single wire, as given in Radiofax, October, p. 13. These are the values of the points at the upper ends of the broken curves in Figure 2, which have been sketched in as a matter of interest.

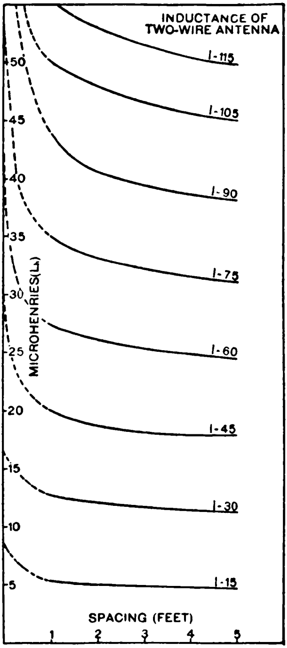


Fig. 2

The sudden decrease in inductance is due to the fact that we have two inductances in parallel. If the wires are placed so far apart that they have no effect upon each other, the inductance of the pair will be simply one-half that of one of the wires; that is, if we would continue the curves in Fig. 2 indefinitely to the right they would approach values of inductance which are equal to one-half the value at the upper ends of the broken curves.

We may thus summarize our conclusions as follows:

The inductance of a two-wire antenna may be increased by

(1) Increasing the length.

(2) Decreasing the spacing.

(3) Increasing the height. This effect is very slight.

In designing an antenna, however, the main idea is to get the capacity and not the inductance of the antenna. The tuning apparatus in the antenna circuit has plenty of inductance with which to do the tuning. Also it must be understood that whatever is done to an antenna of the standard type to increase the inductance will decrease the capacity, and vice versa. This can be immediately seen by comparing the curves in this article with those in the article on Capacity of Two-Wire Antennas, in the February issue of Radiofax. Where curves of capacity slope upward, the corresponding curves of inductance slope downward, and vice versa.

TABLE 3

Inductance of Two-Wire Antenna—Horizontal Portion only.

(Microhenries)

(All lengths in Feet)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
20	5.3	12.3	18.9	26.1	32.6	39.5	46.5	51.6
40	5.3	12.6	19.6	27.0	34.4	41.9	49.4	54.4
60	5.3	12.7	19.8	27.4	35.1	42.7	50.4	55.6
80	5.3	12.7	20.0	27.7	35.2	43.1	51.0	56.3
100	5.3	12.8	20.1	27.8	35.5	43.3	51.3	56.6
120	5.3	12.8	20.2	27.9	35.6	43.4	51.5	56.9
	Spacing 2 Feet							
20	5.0	11.7	18.0	24.9	31.0	37.7	44.3	49.2
40	5.0	12.0	18.7	25.8	32.8	39.9	47.1	51.8
60	5.0	12.1	18.9	26.2	33.6	40.9	48.2	53.3
80	5.0	12.1	19.1	26.4	33.7	41.2	48.8	53.9
100	5.0	12.2	19.2	26.6	33.9	41.5	49.1	54.3
120	5.1	12.2	19.2	26.7	34.0	41.6	49.3	54.5
	Spacing 3 Feet							
20	4.8	11.4	17.5	24.1	30.1	36.6	43.0	47.8
40	4.9	11.7	18.2	25.1	32.0	38.9	45.9	50.4
60	4.9	11.8	18.4	25.5	32.7	39.8	46.9	51.8
80	4.9	11.8	18.6	25.7	32.8	40.2	47.5	52.5
100	4.9	11.8	18.7	25.9	33.0	40.4	47.8	52.9
120	4.9	11.8	18.7	25.9	33.1	40.5	48.0	53.1
	Spacing 4 Feet							
20	4.7	11.2	17.2	23.6	29.5	35.8	42.1	46.8
40	4.8	11.4	17.8	24.5	31.3	38.1	45.0	49.7
60	4.8	11.5	18.0	25.0	32.1	39.1	46.0	50.9
80	4.8	11.6	18.2	25.2	32.2	39.4	46.6	51.5
100	4.8	11.6	18.3	25.4	32.4	39.6	46.9	51.9
120	4.8	11.6	18.4	25.5	32.5	39.8	47.1	52.1
	Spacing 5 Feet							
20	4.6	11.0	16.9	23.3	29.0	35.2	41.4	46.0
40	4.7	11.3	17.5	24.3	30.8	37.5	44.3	48.7
60	4.7	11.4	17.8	24.7	31.6	38.5	45.5	50.1
80	4.7	11.4	18.0	24.9	31.7	38.8	46.0	50.7
100	4.8	11.4	18.1	25.0	31.9	39.1	46.3	51.2
120	4.8	11.4	18.1	25.0	32.0	39.2	46.4	51.4

COIL ANTENNAS

Remove the guess-work in building your loop.

The loop or coil antenna has come into great prominence in the last few years as a result of the ability to use thousands of times the amplification that was previously obtainable. As a means of picking up radio energy emanating from the transmitting station it is inferior to the outdoor antenna, which is generally built on a large scale; but if a coil antenna be built so large that its dimensions approach those of the outdoor antenna it becomes quantitatively as powerful.

Coil antennas can be built to receive over almost any frequency or wave range required. The table on the following page gives values for coils ranging from 10 to 36 inches square, for from 4 to 20 turns of wire, and spacings of turns ranging from ¼ to 1 inch. The table applies accurately to coils of No. 14 wire, but is sufficiently accurate for coils of other sizes of wire. The inductances are given in microhenries and the frequencies in kilocycles per second.

The broadcasting range of frequencies is from 550 to 1350 kilocycles per second. All loops in the table which fall within this range are given in boldfaced type. The frequency ranges have been calculated from the inductance of the coils, for a 0.0005 microfarad variable condenser connected across the terminals of the coil. When the plates of the condenser are completely enmeshed, maximum wave-length is obtained, that is, the minimum frequency. When the condenser plates are completely separated, the ideal condenser would have no capacity. Actual condensers, however, have minimum capacities which are appreciable. In this case we have assumed a minimum capacity equal to 1/10th of the maximum capacity, or 0.00005 microfarad.

If the minimum capacity is lower than this, the higher frequency in the table will be higher than that given and the range of the coil and condenser combination will be greater. To obtain the frequency ranges of loops used with a 0.001 μf. condenser (instead of a 0.0005 μf.), multiply the values in the table by 0.707.

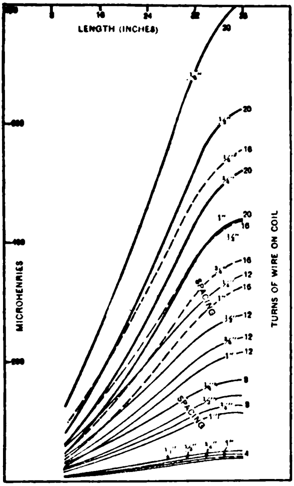
Figures 1 and 2 have been plotted from the values given in the table. Figure 1 shows the variation in inductance for various lengths of side of the coil. The curves set themselves off in groups of four, each curve in a group corresponding to the spacings of the turns, and each group representing a different number of turns. These groups overlap as the number of turns is increased, as indicated by the braces, so that it is possible to obtain the same value of inductance for loops of differing dimensions. The inductance increases generally with the number of turns and the length of the coil. The steepness of the curves also increases considerably as the number of turns is in-

INDUCTANCE AND FREQUENCY RANGES OF COIL ANTENNAS. (Used with a 0.0005 μf. Variable Condenser.)

In this table we have assumed the minimum capacity of the condenser to be 0.00005 μf. (Inductance in microhenries. Frequency in kilocycles per second, and all lengths in inches.)

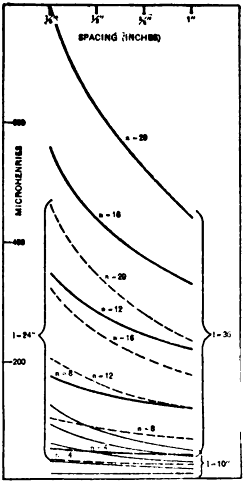
Length of Side of Coil in Inches

No. Turns	10			12			15			18			20			24			28			32			36		
	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.	L μh.	Frequency Max.	Frequency Min.
Spacing of Turns = 1/4 Inch																											
4	10	7120	2252	13	6240	1978	17	5470	1730	22	4700	1520	25	4500	1426	32	3980	1260	39	3605	1142	45	3355	1063	52	3120	988
8	31	4030	1280	41	3510	1112	55	3035	962	71	2670	845	81	2504	792	103	2215	703	126	2005	636	151	1832	580	173	1710	542
12	60	3750	921	78	2546	807	106	2185	692	137	1912	608	158	1790	567	203	1576	500	248	1425	452	291	1320	418	346	1210	383
16	91	2910	748	131	1968	623	165	1752	556	215	1535	487	251	1422	452	323	1252	397	399	1124	357	478	1028	326	559	952	301
20	124	2020	641	168	1736	550	235	1467	465	306	1287	407	357	1192	378	462	1017	332	574	998	297	688	858	271	809	792	250
Spacing of Turns = 1/2 Inch																											
4	9	7500	2375	11	6780	2150	15	5820	1842	19	5170	1635	22	4800	1522	28	4260	1347	34	3855	1222	40	3555	1126	46	3315	1050
8	24	4580	1456	32	3980	1260	44	3380	1075	57	3980	943	66	2770	878	85	2440	773	104	2206	685	127	2000	633	145	1866	592
12	43	3430	1086	57	2980	943	80	2515	798	105	2195	696	123	2030	643	161	1773	562	198	1596	507	239	1453	450	281	1343	426
16	63	2830	898	86	2425	768	121	1858	648	160	1780	563	188	1642	521	245	1437	456	308	1282	407	374	1162	369	439	1072	340
20	82	2485	788	113	2120	672	162	1766	561	219	1518	482	259	1396	443	342	1218	386	432	1082	343	526	983	311	625	901	285
Spacing of Turns = 3/4 Inch																											
4	8	7960	2520	10	7120	2252	14	6020	1907	17	5470	1730	20	5030	1592	25	4510	1427	31	4030	1278	36	3750	1186	43	3430	1086
8	20	5025	1593	27	4330	1372	38	3650	1156	49	3210	1017	57	2980	945	74	2610	828	92	2345	743	112	2126	673	129	1982	628
12	34	3875	1223	46	3320	1052	66	2770	878	87	2410	763	103	2215	703	135	1938	613	169	1732	548	204	1573	498	243	1442	457
16	47	3280	1040	66	2770	878	96	2295	728	129	1932	628	153	1820	577	204	1573	498	258	1400	443	315	1267	402	374	1163	368
20	61	2875	913	84	2450	777	128	1990	630	68	1735	550	205	1572	498	276	1355	329	354	1194	379	434	1080	342	522	986	312
Spacing of Turns = 1 Inch																											
4	7	8510	2695	9	7500	2375	12	6500	2060	16	5630	1783	19	5170	1635	24	4600	1456	29	4175	1324	35	3805	1204	40	3555	1126
8	17	5460	1726	24	4580	1456	33	3915	1242	44	3390	1075	51	3150	998	67	2750	870	83	2470	782	102	2230	706	118	2070	657
12	28	4260	1346	39	3605	1142	54	3060	971	75	2600	823	90	2370	752	119	2060	653	150	1836	582	182	1670	528	217	1530	484
16	38	3650	1156	53	3090	980	79	2530	803	108	2165	687	129	1982	627	174	1705	542	222	1512	478	269	1372	433	328	1242	393
20	47	3285	1040	66	2770	878	101	2240	709	140	1902	602	170	1727	547	232	1480	468	300	1208	412	372	1167	370	441	1072	340



creased. It is noticed that the increase of inductance between spacings of ¼ and ½ inch is greater than the increase between 1 and ¾ inch.

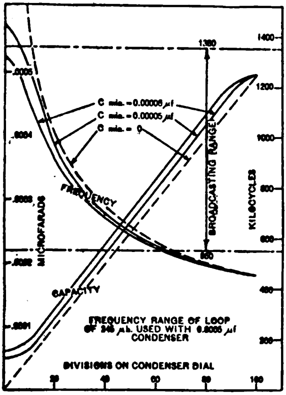
From these curves wecan see that the inductance of a loop increases (1) as the length increases, (2) as the number of turns increases, (3) as the spacing decreases. The effect of the spacing may be seen more clearly in Figure 2. Only three sets of curves have been plotted here, for the sake of clarity, as the curves overlap, each set of curves being for a different length of side. The inductance increases very rapidly for the larger number of turns as the spacing is decreased, and all show a tendency to become horizontal toward the right. This seems to indicate that as far as the inductance of the coil is concerned, nothing is gained by making the spacing of a 10-inch coil greater than about 1 inch, a 24-inch coil greater than about 1½ inches, or a 36-inch coil greater than about 2 inches. This can be visualized by mentally extending the curves to the right.



Referring to the table, it is interesting to note that greater frequency ranges may be secured by the use of loops having a small number of turns. Large ranges may be desirable under certain conditions but in general would result in extreme selectivity, perhaps too selective for ordinary purposes. Moreover, to come within the broadcasting frequency range with a loop of small number of turns would necessitate a great length of side of the loop. Referring to the 36-inch loop having a spacing of ¼ inch, the range for 4 turns is 3,120 to 988 kilocycles. To bring the lower frequency down to 550, the lower

limit of the broadcasting range, would require a loop beyond the limits of the table, perhaps 4 or 5 feet long.

The choice of a variable condenser to use with any given loop is an important item to consider. The main point to consider is that of the minimum capacity, that is, the capacity possessed by the condenser when the plates are completely separated. The ideal condenser has no minimum capacity. Referring to Figure 3, the broken line starting from the origin of co-ordinates gives the capacity of the condenser for various settings of the dial. The dial is here supposed to be divided into 100 equal divisions in a semi-circumference. If the frequency of the system comprising a loop whose inductance is 245 microhenries and an ideal condenser whose maximum capacity is 0.0005 microfarad is calculated, the broken curve shown would be obtained. (The loop chosen is given in the table—24 inches on a side, 16 turns of wire spaced ½ inch apart.)



The ideal condenser does not exist. Similar curves have been computed for condensers whose minimum capacities are 0.00005 and 0.00006 microfarad. The broadcasting frequency range is indicated on the chart, and it will be noticed that the condenser whose minimum capacity is 0.00005 µf. embraces the whole range, with a little to spare on either side, while the other condenser, whose minimum capacity is 0.00006 µf., falls short of the higher frequency required.

These figures will be different for different combinations of loop and condenser. At any rate, it is best to select condensers whose minimum capacities are low. How low this should be for a condenser to be considered "good" is yet an unanswered question. In the condenser test which we are conducting we will find the answer to this question and will soon be enabled to impart it to our readers.

Loop antennas possess capacity as well as any other electrical conductor, and theoretically this capacity should be taken into account in the calculations. But this coil capacity is generally so low as compared with the condenser used with the loop that we may neglect it with safety, for our calculations will then be in error by an exceedingly negligible amount. The capacity of 4-foot coil antennas varies from 50 to 100 micro-microfarads, which is very small compared with 0.0005 microfarad.

THREE-WIRE ANTENNAS

In Radiofax for February and March, 1924, there appeared articles covering the constants for two-wire antennas. Single-wire antennas were treated in the October and November issues of 1923. As a result of our success in simplifying the calculations involved in the selection of the proper dimensions for single and two-wire antennas we have received many requests for similar information on three and four-wire arrangements. The following material covers inductance and capacity values for the three-wire type. The four-wire antenna will be taken up in the March issue.

Capacity—The values in Table 1 were computed from formulas given in Circular No. 74 of the U. S. Bureau of Standards and apply to wire approximately No. 12 B. & S. gage. The curves in Figure 1 have been plotted from the values in the table. The curves for l = 75 feet and l = 105 feet have been omitted because they overlap the others and thus would cause confusion.

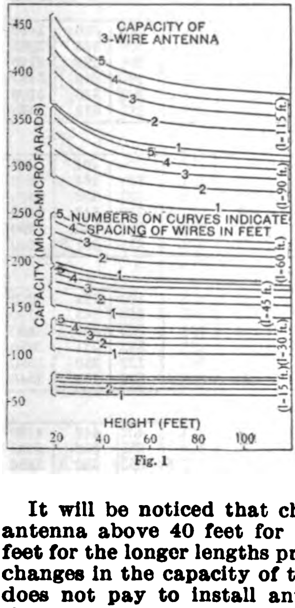


Fig. 1

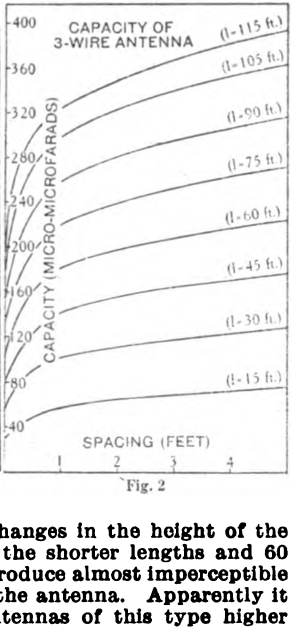


Fig. 2

It will be noticed that changes in the height of the antenna above 40 feet for the shorter lengths and 60 feet for the longer lengths produce almost imperceptible changes in the capacity of the antenna. Apparently it does not pay to install antennas of this type higher than 40 to 60 feet over ground if the desideratum is solely increased capacity. Of course, an increase of height will always improve reception.

Since height has little effect upon the capacity, we have in Fig. 2 used a constant height of 60 feet. It is seen that to increase the spacing between the wires more than one foot does not increase the capacity appreciably, therefore two-foot spacing should be considered maximum.

Inductance—In determining the inductance of more than one wire, the following formula should be used:

$$L_h = \frac{L_h' + (n-1)\,M}{n} - kl$$

in which the subscript $_h$ refers to the horizontal portion of the antenna only, L'_h is the self-inductance of one of the wires, M is the mutual inductance between any two

Table 1

Capacity of Three-Wire Antenna—Horizontal Portion Only (Micro-microfarads)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115	1000
	Spacing 1 Foot								
20	59.6	106.8	153	197.5	244	289.5	336	366	3410
40	58.3	102.5	145	186	227	268	308	335	3261
60	58.0	102	142	182	221	259	298	324	3180
80	57.9	102	141	180.2	218.5	255	294	318	3140
100	57.6	102	140.3	178.5	217	253.5	290	315	3100
120	57.5	101	140.2	178	216	252.0	287	312	3070
	Spacing 2 Feet								
20	66.9	118.0	167.5	217	267	317	368	401	3760
40	65.1	113.2	159	199.5	247	291	334	364	3590
60	64.8	111.5	156.3	198.5	240.3	281.5	323	350	3490
80	64.5	111.0	154.5	196	237	277.5	318	343	3430
100	64.4	110.8	153.5	194.5	235	275	314	340	3390
120	64.4	110.2	153	193.5	234	273	311	337.5	3350
	Spacing 3 Feet								
20	72.0	126	177.8	230.5	283.5	336	389	424	4000
40	69.8	120.5	168.0	215	261	307	352	383	3790
60	69.3	118.5	164.8	209.5	254	296	340	368	3690
80	69.1	117.8	162.8	207.0	250	291	334	361	3630
100	69.0	117.3	162.0	205.0	248	289	329	356	3590
120	69.0	117.0	161.3	204.0	246	286.5	326	353	3540
	Spacing 4 Feet								
20	76.2	132	186.0	241	296.5	351	407	443	4180
40	73.7	126.5	175.3	224	272	319	366	398	3965
60	73.1	124.3	171.9	218	264	307.5	353	382.5	3850
80	73.0	123.3	169.7	215.5	260	302	346	373	3770
100	72.9	122.8	168.5	213.5	257	299.5	341	370	3730
120	72.8	122.5	168.3	212	256	297	338	366	3690
	Spacing 5 Feet								
20	79.7	137.5	193.0	250.0	307	363.5	421	459	4350
40	77.0	131.3	181.5	231.5	281	329.5	378	410	4100
60	76.4	128.8	177.8	225	273	317	363.5	394	3990
80	76.2	128.0	175.4	222.0	268	311.5	356	384.5	3900
100	76.0	127.3	174.3	220.3	266	308.5	351	380	3860
120	76.0	127.0	174.0	219	264	306	348	377	3810

adjacent wires, all in microhenries, l is the length of the antenna in feet, n is the number of wires and k is a constant depending upon the number of wires.

n—	2	3	4	5	6	7	8	9	10
k—	.0	.009	.019	.028	.036	.044	.051	.057	.062

Table 2, page 13 of Radiofax for October, 1923, gives values of L'_h for various heights and lengths. Values of M are given in Table 1, page 33 of Radiofax for March, 1924. Where the number of wires is three, k equals .009 and the above formula becomes:

$$L_h = \frac{L'_h + 2M}{3} - .009\,l$$

TABLE 2

Inductance of Three-Wire Antenna—Horizontal Portion Only (Microhenries)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
20	4.1	9.6	15.0	20.8	26.0	31.5	37.3	41.3
40	4.2	9.9	15.7	21.7	27.7	34.0	40.2	44.3
60	4.2	10.0	15.9	22.1	28.2	34.7	41.1	45.4
80	4.2	10.0	16.0	22.4	28.5	35.1	41.7	46.1
100	4.2	10.1	16.1	22.5	28.8	35.4	42.0	46.5
120	4.2	10.1	16.2	22.5	28.9	35.5	42.3	46.8
	Spacing 2 Feet							
20	3.7	8.8	13.8	19.2	23.9	29.1	34.3	38.1
40	3.8	9.1	14.4	20.1	25.6	31.3	37.1	40.8
60	3.8	9.2	14.7	20.5	26.4	32.2	38.2	42.3
80	3.8	9.2	14.8	20.7	26.5	32.6	38.8	42.9
100	3.8	9.3	14.9	20.9	26.7	32.9	39.2	43.4
120	3.8	9.3	14.9	20.9	26.8	33.1	39.4	43.6
	Spacing 3 Feet							
20	3.5	8.4	13.0	18.2	22.7	27.6	32.6	36.2
40	3.6	8.7	13.7	19.2	24.4	29.9	35.4	39
60	3.6	8.8	14.0	19.6	25.2	30.8	36.5	40.4
80	3.6	8.8	14.1	19.8	25.3	31.2	37.1	41.1
100	3.6	8.8	14.3	19.9	25.5	31.5	37.4	41.5
120	3.6	8.8	14.3	19.9	25.6	31.6	37.7	41.7
	Spacing 4 Feet							
20	3.4	8.3	12.8	17.5	21.8	26.7	31.4	34.9
40	3.5	8.3	13.3	18.5	23.6	28.8	34.2	37.7
60	3.5	8.4	13.5	18.9	24.4	29.8	35.3	39.1
80	3.5	8.5	13.6	19.1	24.5	30.2	35.9	39.7
100	3.5	8.5	13.7	19.3	24.7	30.4	36.2	40.2
120	3.5	8.6	13.8	19.3	24.8	30.6	36.5	40.4
	Spacing 5 Feet							
20	3.3	7.9	12.2	17.0	21.2	25.9	30.5	33.9
40	3.3	8.1	12.9	18.0	22.9	28.1	33.3	36.7
60	3.4	8.2	13.1	18.4	23.7	29.0	34.4	38.1
80	3.4	8.3	13.3	18.6	23.8	29.4	35.0	38.7
100	3.4	8.3	13.3	18.7	24.0	29.7	35.4	39.2
120	3.4	8.3	13.3	18.8	24.1	29.8	35.5	39.3

We have calculated Table 2 from this formula. Fig. 3 has been plotted from Table 2. The curves for l = 105 feet have been omitted to avoid confusion. The curves in Fig. 3 are arranged in groups of 5 each. Each group is for a different length. The individual curves of each group represent the five different spacings given in Table 2.

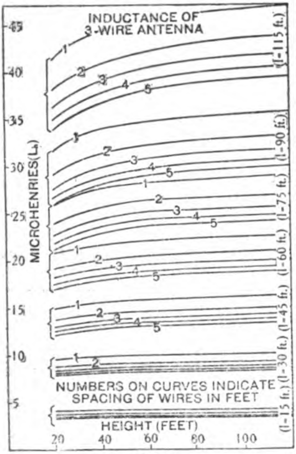


Fig. 3

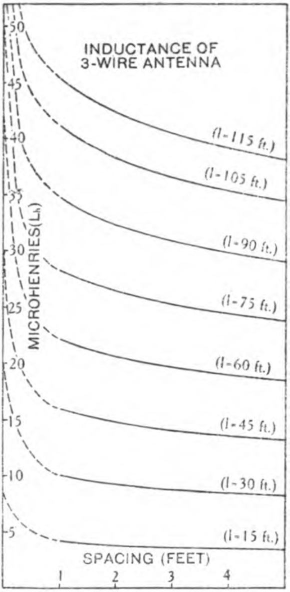


Fig. 4

A study of Fig. 3 will show that height has very little effect on inductance after an elevation of 35 feet is attained. It will also be seen that inductance decreases as spacing between wires is increased. This decrease is rapid at first as we separate the wires but soon falls to an inappreciable amount as the wires are further and further removed from each other. This can be seen more clearly in Fig. 4. A constant height of 60 feet has been used in drawing the curves in Fig. 4 but, as we have seen, the height has little effect on inductance above 35 feet. The curves, therefore, can be considered applicable to any reasonable height above 35 feet.

If we imagine the three wires to be brought so close together that they coincide, we have, for zero spacing, the inductance of a single wire, as given in Radiofax for October, 1923. The curves have been continued with dotted lines to these points.

The curves for the constants of the three-wire antenna have, as was to be expected, an appearance very similar to the curves for corresponding values of the two-wire antenna. The added wire increases the capacity and decreases the inductance.

THREE-WIRE ANTENNAS HAVING HEIGHTS LESS THAN 20 FEET

A number of cases have come to our attention where three-wire antennas have been erected having heights of only 5, 10 or 15 feet. Although such low antennas are not to be recommended for reception of distant signals there are times when low antennas show advantages in the elimination of atmospheric disturbances. In order to give our readers the necessary data for computing the constants for low antennas the following information is presented.

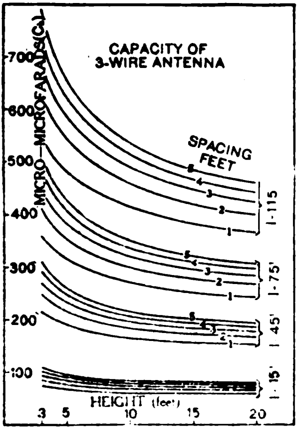


Fig. 1

Capacity.—The values in Table 1 were computed from the same formula used for the higher antennas. Fig. 1 has been plotted from Table 1. It will be noted that the capacity decreases rapidly as the height is increased, especially for the longer antennas.

TABLE 1
Capacity of Three-Wire Antenna—Horizontal Portion Only (Micro-Micro-Farads)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
3	74.9	146	217	288	360	432	503	552
5	67.7	129	191	253	315	378	440	482
10	62.3	114.5	166	221	272	325	379	415
15	61.2	109	157	205	246	302	351	383
	Spacing 2 Feet							
3	86.5	168	250	331	413	497	578	634
5	77.1	146.5	216	286	356	427	497	545
10	70.3	127.5	185	243	301	360	419	459
15	65.8	121	173.5	226	279	332	385	421
	Spacing 3 Feet							
3	95.3	184	274	364	454	545	634	695
5	84.2	158.5	234	310	385	462	538	588
10	75.9	137	198	260	321	386	448	491
15	70.8	129.5	185	241	296	353	409	448
	Spacing 4 Feet							
3	103	198	294	390	487	585	682	748
5	89.8	168.5	248	329	409	490	571	625
10	80.5	145	208.5	273	338	404	471	516
15	78.5	136	194	252	310	370	429	467
	Spacing 5 Feet							
3	109.5	210	311	414	517	620	723	793
5	94.7	177	261	344	483	515	600	655
10	84.5	151	217	285	353	422	490	537
15	82.3	141.5	201	262	321	384	445	485

Curves for antennas 30, 60, 90 and 105 feet have been omitted be cause they overlap and would thus cause confusion; complete data, however, are given in the table.

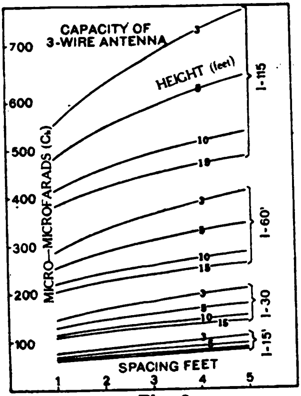


Fig. 2

What has been said about the influence of various spacing between wires for the higher antennas is also true for low antennas. This is more clearly shown in Fig. 2. In the corresponding curves for the higher antennas the influence of height was so slight that it could be disregarded. It can be seen that this is decidedly not true for the low antennas, for here a small change in height has a very appreciable influence on capacity. The gain in capacity resulting from increasing the spacing is greater for low antennas than for higher ones. The greater the spacing the less the gain in capacity for each additional foot of width.

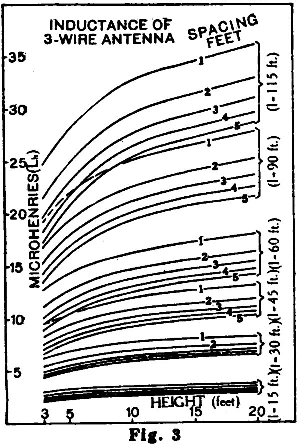


Fig. 3

Inductance.—The values in Table 4 are derived from the same formula used in computing the figures in the corresponding table for high antennas. The values of self inductance L'_h and the mutual inductance M are given in Table 2 and 3, respectively. These tables supplement the corresponding tables in Radiofax, October, 1923 and March, 1924.

The curves in Fig. 3 were plotted from the values given in Table 4. It can be seen that the inductance increases rapidly when the height increases. The rate of increase becomes less as height increases. The influence of spacing is clearly shown in Fig. 4. The height factor can not here be neglected as was done in the corresponding data on high antennas.

The inductance decreases with increased spacing but the rate of decrease becomes less for the larger spacings.

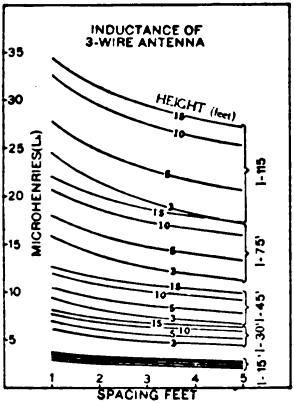


Fig. 4

The great influence of height on inductance for low antennas can be visualized by noting that in Fig. 4 a 75-foot antenna 15 feet high has about the same inductance as a 115-foot antenna 3 feet high. Both antennas being of the three-wire type, having 5-foot spacing.

The curves for some lengths have been omitted from Fig. 4 to avoid confusion. The missing data will be found in the table.

TABLE 2

Inductance of Single Horizontal Wire (Microhenries)

Height in Feet	Length (Feet)							
	15	30	45	60	75	90	105	115
3	6.5	13.4	20.2	27.0	33.9	40.8	47.7	52.3
5	6.8	14.1	21.4	28.7	36.1	43.4	50.6	55.6
10	7.1	14.9	22.8	30.7	38.7	46.6	55.0	60.3
15	7.2	15.3	23.5	31.7	40.1	48.2	56.5	62.1

We still have available a limited number of copies of Radiofax for October and November 1923 and February and March 1924.

These are the issues mentioned on page 13 that gave the data for one and two wire antennas. Information is also given on the constants for the lead-in wire and loading capacities and inductances.

For those who have lost these early issues we offer the group of four for 75 cents.

TABLE 3

Mutual Inductance of Two Parallel Grounded Wires (Microhenries)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
3	1.4	2.9	4.6	6.3	7.9	9.5	11.1	12.3
5	1.7	3.7	5.8	7.9	10.0	12.2	14.3	15.6
10	1.9	4.5	7.2	9.9	12.7	15.4	18.6	20.4
15	2.0	4.9	7.9	10.9	14.0	17.0	20.1	22.2
	Spacing 2 Feet							
3	0.8	1.8	2.8	3.8	4.8	5.8	6.8	7.5
5	1.1	2.5	4.0	5.4	6.9	8.4	9.9	10.8
10	1.4	3.3	5.4	7.4	9.5	11.6	14.2	15.6
15	1.5	3.7	6.0	8.4	10.9	13.3	15.8	17.5
	Spacing 3 Feet							
3	0.5	1.1	1.7	2.3	3.0	3.6	4.2	4.7
5	0.8	1.8	2.9	4.0	5.1	6.2	7.3	8.0
10	1.0	2.6	4.3	6.0	7.7	9.5	11.7	12.8
15	1.1	3.0	5.0	7.0	9.1	11.1	13.2	14.7
	Spacing 4 Feet							
3	0.3	0.6	1.0	1.4	1.7	2.1	2.5	2.7
5	0.6	1.4	2.2	3.0	3.9	4.7	5.6	6.0
10	0.9	2.2	3.6	5.0	6.5	7.9	9.9	10.8
15	1.0	2.5	4.3	6.0	7.8	9.6	11.5	12.7
	Spacing 5 Feet							
3	0.1	0.3	0.4	0.6	0.8	0.9	1.1	1.2
5	0.4	1.0	1.6	2.2	2.9	3.6	4.2	4.6
10	0.7	1.8	3.0	4.2	5.5	6.8	8.5	9.3
15	0.8	2.2	3.7	5.3	6.9	8.5	10.1	11.2

TABLE 4

Inductance of Three-Wire Antennas—Horizontal Portion Only (Microhenries)

Height in Feet	Length (Feet) 15	30	45	60	75	90	105	115
	Spacing 1 Foot							
3	3.0	6.2	9.4	12.7	15.9	19.1	22.4	24.6
5	3.3	6.9	10.4	14.3	18.0	21.8	25.5	27.9
10	3.5	7.7	12.0	16.3	20.7	25.0	29.8	32.7
15	3.6	8.1	12.7	17.3	22.0	26.6	31.3	34.5
	Spacing 2 Feet							
3	2.6	5.4	8.2	11.0	13.8	16.7	19.5	21.4
5	2.9	6.1	9.4	12.6	16.0	19.3	23.5	24.7
10	3.2	6.9	10.8	14.6	18.6	22.5	26.9	29.5
15	3.3	7.3	11.4	15.6	20.0	24.1	28.5	31.4
	Spacing 3 Feet							
3	2.4	4.9	7.5	10.0	12.6	15.2	17.8	19.6
5	2.7	5.6	8.7	11.7	14.7	17.8	20.8	22.9
10	2.9	6.4	10.1	13.7	17.3	21.1	25.2	27.6
15	3.0	6.8	10.8	14.7	18.7	22.7	26.7	29.5
	Spacing 4 Feet							
3	2.2	4.6	7.0	9.4	11.8	14.2	16.6	18.2
5	2.5	5.4	8.2	11.0	14.0	16.8	19.7	21.5
10	2.8	6.2	9.6	13.0	16.6	20.0	24.0	26.3
15	2.9	6.5	10.3	14.0	17.9	21.7	25.6	28.2
	Spacing 5 Feet							
3	2.1	4.4	6.6	8.9	11.2	13.4	15.7	17.2
5	2.4	5.1	7.8	10.5	13.3	16.1	18.7	20.6
10	2.7	5.9	9.2	12.5	15.9	19.3	23.1	25.3
15	2.8	6.3	9.9	13.6	17.3	20.9	24.6	27.2

MULTI-WIRE ANTENNAS

Supplementing the data already published on single, two and three-wire antennas and the data on four-wire antennas to appear soon, we present the following information which was compiled for the purpose of demonstrating the effect produced by each additional wire.

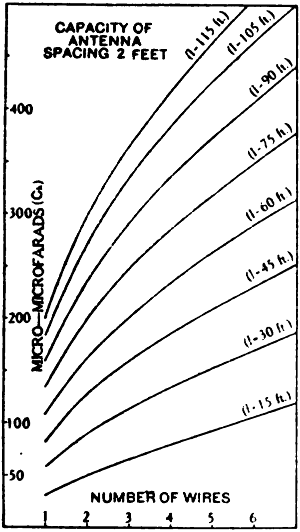


Fig. 1

For simplification we have limited this material to antennas 40 feet high with two-foot spacing between wires. The tables and curves give constants for 1, 2, 3, 4, 5, 6 and 7 wires in parallel. The constants for a greater number of wires can be approximately obtained by drawing extensions to the curves given. The continuation will be very close to straight lines.

Capacity.—Table 1 gives the capacity of the wires for various lengths. Fig. 1 presents the same data graphically. It will be seen that capacity increases at first rapidiy and than at a slower

TABLE 1

Capacity of Horizontal Portion of Antennas, Height 40 Feet, Spacing 2 Feet (Micro-Micro-farads)

Length in Feet	Number of Horizontal Wires						
	1	2	3	4	5	6	7
15	30.5	49.7	65.0	78.8	92.3	105.8	119.5
30	57.0	89.0	113.2	133.5	152.5	169.5	187.0
45	82.8	127.0	159.0	185.5	209.0	231.0	252.0
60	108.0	163.0	199.5	235.0	263.5	290.0	314.0
75	133.5	199.5	247.0	285.0	318.0	349.0	378.0
90	158.0	236.0	291.0	335.0	374.0	407.0	441.0
105	183.0	271.0	334.0	384.0	424.0	465.0	502.0
115	199.0	297.0	364.0	417.0	463.0	506.0	545.0

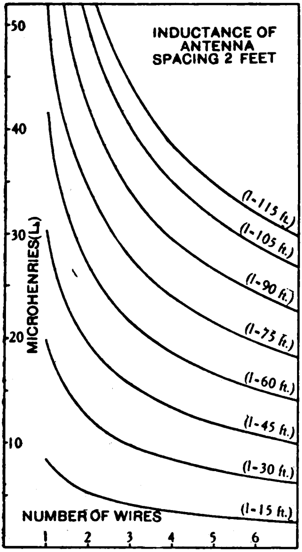


Fig. 2

rate as the number of wires is increased. Beyond four wires the increase per wire is approximately constant for each additional wire.

Inductance.—Table 2 gives the inductance of the wires for various lengths. Fig. 2 presents the data graphically. The inductance decreases at first rapidly and then at a lower rate as the number of wires is increased. If there was no mutual inductance, the inductance for 2 wires would be one half and for 3 wires one-third of the value for a single wire.

The bends of the curves occur at the point for three or four wires. Beyond the four wire point the decrease in inductance is about the same for each additional wire.

TABLE 2

Inductance of Horizontal Portion of Antennas, Height 40 Feet, Spacing 2 Feet (Microhenries)

Length in Feet	Number of Horizontal Wires						
	1	2	3	4	5	6	7
15	8.5	5.3	4.2	3.5	3.0	2.7	2.4
30	19.9	12.6	9.9	8.5	7.5	6.7	6.2
45	30.4	19.6	15.7	13.4	11.9	10.9	10.0
60	41.6	27.0	21.7	18.6	16.6	15.2	14.1
75	52.4	34.4	27.7	24.0	21.5	19.7	18.2
90	63.5	41.9	34.0	29.5	26.5	24.4	22.6
105	74.6	49.4	40.2	34.9	31.4	28.9	26.9
115	81.8	54.4	44.3	38.5	34.7	32.0	29.8

There will be no compulsory drilling or cruising, but if desired, an opportunity may be obtained to cruise on a naval ship for 15 days during the summer. Several ships have been allotted to the Naval Reserve Force and cruises have been planned from the several naval districts to some interesting terminals Upon these cruises training is given to the Reservist in his particular branch of service. The radioman handles actual naval traffic problems, codes and decodes messages, maintains his apparatus and sometimes is given some experimental training. It has been planned to give a limited number of radiomen this opportunity the coming summer, but it may be necessary in some instances for the candidate to bear his own expense on the cruises, because of lack of appropriation of sufficient funds for this purpose. The expenses involved for a candidate in some Naval Districts will include his transportation to and from his home, and the cost of his subsistance which would be approximately ten dollars for the total time of the fifteen days.

A list of the commandants of the nearest Naval Districts where anyone interested may obtain further information is given below.

Commandant, First Naval District, Navy Yard, Boston.

Commandant, Third Naval District, South & Whitall Sts., New York.

Commandant, Fourth Naval District, Navy Yard, Philadelphia.

Commandant, Fifth Naval District, Naval Operating Base, Hampton Roads, Va.

Commandant, Sixth Naval District, Navy Yard, Charleston, S. C.

Commandant, Seventh Naval District, Naval Station, Key West, Fla.

Commandant, Eighth Naval District, Naval Station, New Orleans.

Commandant, Ninth Naval District, Naval Training Station, Great Lakes, Ill.

Commandant, Eleventh Naval District, Naval Operating District Base, San Diego, Calif.

Commandant, Twelfth Naval District, Room 313, Custom House, San Francisco.

Commandant, Thirteenth Naval District, Harbor Ave., & Georgia Sts., Seattle.

A quota has been assigned to each district and no enrollments will be made after it has been completed.

LIGHTNING ARRESTORS

We have concluded from the discussion in Radiofax of April, 1925, that a lightning arrestor is a necessary addition to receiving sets. Furthermore, in many localities an arrestor is required by the Underwriters. They desire that each arrestor have a certain break-down voltage and a certain type of construction, in order to give ample protection. However, it must be recognized that protection must be accompanied by another feature. It is that the arrestor must not dissipate any energy required for the suitable operation of the receiving set. It must have such electrical constants that at radio frequencies maximum energy is available for detection or amplification. An arrestor which does not meet all of the above requirements must be classified as a poor arrestor. It may have excellent protective features, but if it short circuits the receiving set of what use is it?

In order to discover what type of construction produces a poor arrestor we decided to make an actual test on all of the available lightning arrestors on the market. The manufacturers of arrestors gave us their co-operation by submitting twenty-nine different types to an actual test. Before it is possible to interpret the results one must understand in what manner an arrestor produces a loss of energy.

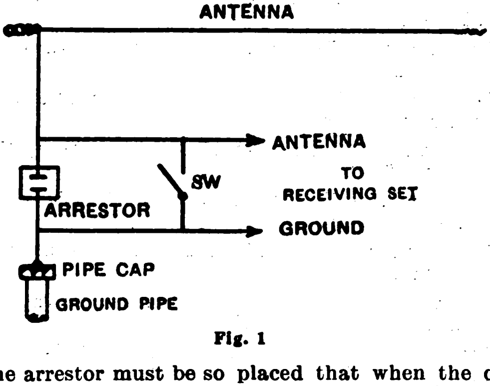


Fig. 1

The arrestor must be so placed that when the difference of potential between the antenna and ground reaches a predetermined value, generally 500 volts or less, the energy jumps across the arrestor gap. Without the arrestor such an arc over might ruin the receiving set.

An antenna switch may also be used if additional protection is desired.

CALCULATIONS OF FOUR-WIRE ANTENNAS

We have in past issues furnished technical material for one, two and three-wire antennas, and present in this article material for the four-wire antennas.

Capacity—Table 1 has been calculated from formulas given by the U. S. Bureau of Standards. Fig. 1 has been plotted from Table 1. It will be noticed that changes in the height of the antenna above forty feet produce almost imperceptible changes in the capacity of the antenna. Therefore it does not pay to build a four-wire antenna higher for any reason other than to increase range of reception or to avoid proximity with neighboring buildings, etc.

The capacity increases when the spacing increases, but apparently it does not pay to space the wires more than two feet. This point is more clearly brought out in Fig. 2. These curves are for 60 feet height, but as we have seen the height has very little influence upon the capacity. The curves are drawn out to the points, where the four wires coincide, that is the capacity of a single-wire antenna. It will be seen that the slopes of the curves are greater for the greater lengths. This means that we may use greater spacings for the greater lengths.

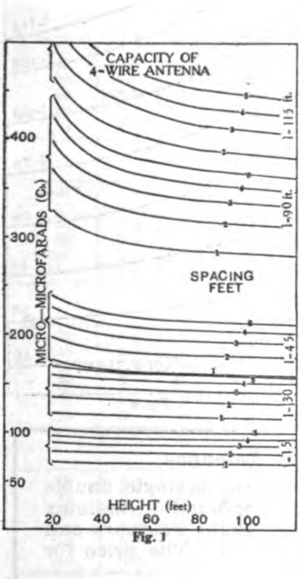


Fig. 1

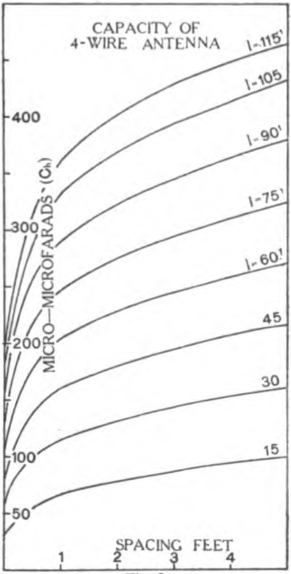


Fig. 2

Inductance—In determining the inductance of antennas of four wires, the following formula is to be used:

$$L_h = \frac{L'_h + 3M}{4} - 0.019\, l$$

The subscript $_h$ refers to the horizontal portion of the antenna only. L'_h the inductance of one of the wires, is given in Table 2, page 13, of the October Radiofax; M, the mutual inductance between any two adjacent wires is given in Table 1, March Radiofax, 1924, all in microhenries; l, is the length of the antenna in feet. Table 2 has been calculated from this formula. Fig. 3 has been plotted from this table. As was the case for the capacity, it will be seen that height has very little effect upon the inductance when the height is more than 40 feet. Below this, changes in height

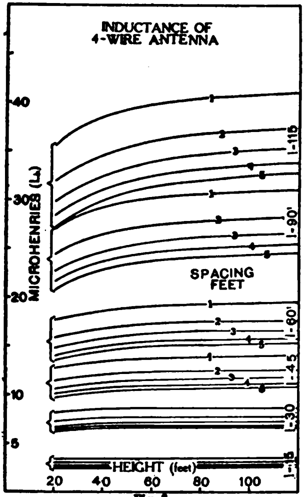


Fig. 3

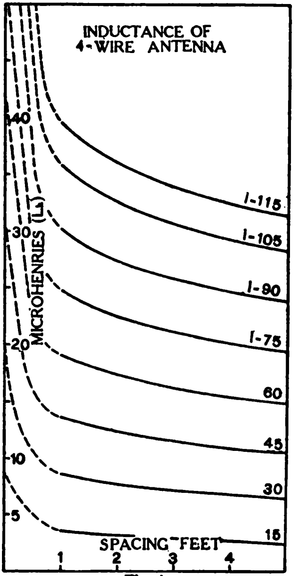


Fig. 4

1, 2 and 3 Wire Antennas

Articles similiar to this one covering single, double and triple wire antennas will be found in Radiofax for October and November 1923, February and March 1924, and January 1925. The price for all five issues is $1.00.

cause perceptible changes in the inductance. The influence of the spacing is more clearly shown in Fig. 4. These curves are for 60 feet height, but as we have pointed out the height has little influence on the inductance. The curves are drawn out with dotted lines to the zero spacing, where the four wires coincide. It will be seen that it does not pay to space the wires more than two feet, if you want to decrease the inductance. The greatest variation in inductance is for the smaller spacings.

TABLE 1

Capacity of Four-Wire Antenna—Horizontal Portion Only (Micro-microfarads)

Height in Feet	Length (Feet)							
	15	30	45	60	75	90	105	115
Spacing 1 Feet								
20	3.4	8.1	12.7	17.7	22.3	27.0	32.0	35.5
40	3.5	8.5	13.4	18.7	24.0	29.5	34.9	38.5
60	3.5	8.6	13.6	19.1	24.8	30.2	35.8	39.6
80	3.5	8.6	13.8	19.3	24.8	30.6	36.4	40.4
100	3.5	8.6	13.9	19.4	25.1	30.9	36.8	40.7
120	3.5	8.6	14.0	19.5	25.2	31.0	37.0	41.0
Spacing 2 Feet								
20	3.0	7.2	11.4	15.9	20.0	24.3	28.7	31.9
40	3.0	7.6	12.0	16.8	21.6	26.5	31.4	34.6
60	3.1	7.7	12.3	17.3	22.4	27.4	32.6	36.1
80	3.1	7.7	12.4	17.5	22.5	27.8	33.2	36.8
100	3.1	7.7	12.5	17.6	22.7	28.1	33.5	37.2
120	3.1	7.7	12.5	17.6	22.8	28.3	33.8	37.4
Spacing 3 Feet								
20	2.7	6.8	10.5	14.8	18.6	22.7	26.8	29.8
40	2.8	7.0	11.2	15.8	20.2	24.9	29.6	32.6
60	2.8	7.1	11.5	16.2	21.1	25.8	30.6	33.9
80	2.8	7.2	11.6	16.6	21.2	26.2	31.2	34.7
100	2.8	7.2	11.8	16.6	21.4	26.5	31.6	35.1
120	2.8	7.2	11.8	16.6	21.5	26.6	31.8	35.3
Spacing 4 Feet								
20	2.6	6.6	10.2	14.0	17.6	21.6	25.4	28.3
40	2.7	6.7	10.7	15.1	19.3	23.7	28.2	31.1
60	2.7	6.8	10.9	15.4	20.2	24.7	29.3	32.5
80	2.7	6.8	11.0	15.6	20.3	25.0	29.9	33.2
100	2.7	6.8	11.2	15.8	20.5	25.3	30.2	33.6
120	2.7	6.9	11.2	15.8	20.6	25.5	30.5	33.9
Spacing 5 Feet								
20	2.4	6.2	9.6	13.5	16.9	20.7	24.4	27.1
40	2.5	6.4	10.3	14.5	18.6	22.9	27.2	30.0
60	2.5	6.5	10.5	14.9	19.4	23.8	28.3	31.4
80	2.5	6.6	10.7	15.1	19.5	24.1	28.9	32.0
100	2.6	6.6	10.8	15.2	19.7	24.5	29.3	32.5
120	2.6	6.6	10.8	15.3	19.8	24.6	29.4	32.8

TABLE 2

Inductance of Four-Wire Antenna—Horizontal Portion Only (Microhenries)

Height in Feet	Length (Feet)							
	15	30	45	60	75	90	105	115
Spacing 1 Foot								
20	70.0	120	175	226	277	328	380	415
40	68.5	118	164	210	256	300	346	375
60	67.8	116	161	205	248	291	333	361
80	67.5	116	160	202	245	286	327	355
100	67.5	114	159	201	243	284	323	350
120	67.5	114	158	200	241	281	321	347
Spacing 2 Feet								
20	81.3	137	198	255	312	370	427	464
40	79.0	136	185	236	285	335	385	419
60	78.7	132	181	229	276	323	369	402
80	78.3	131	179	226	272	318	361	390
100	78.2	129	178	224	270	313	357	386
120	78.2	129	177	223	268	311	354	382
Spacing 3 Feet								
20	90.8	149	214	276	337	399	461	500
40	87.5	146	201	253	306	359	412	448
60	86.7	144	195	246	295	345	394	429
80	86.4	142	194	242	291	339	385	415
100	86.3	136	191	240	288	334	380	411
120	86.3	140	191	239	286	332	377	406
Spacing 4 Feet								
20	97.5	160	229	293	358	423	488	534
40	94.5	156	212	268	323	377	433	470
60	93.7	153	207	259	311	363	413	448
80	93.3	151	205	256	305	355	404	433
100	93.0	153	202	253	302	351	398	429
120	93.0	153	202	252	300	348	395	426
Spacing 5 Feet								
20	104	169	241	308	375	444	512	557
40	100.5	164	222	280	337	394	451	488
60	99.8	161	217	271	324	379	431	464
80	99.3	159	214	267	318	370	421	453
100	99.0	153	211	264	316	365	413	447
120	99.0	153	211	263	312	361	410	441

ANTENNA SUBSTITUTE

It has been found that the "Balkite B", the plate current supply devise manufactured by the Fansteel Products Co., can perform a dual role. If the antenna post of the receiver is connected to the ground wire and the ground post of the receiver is connected to the post marked G on the Balkite B it will be found in most cases that this arrangement will function well as a substitute for an outdoor antenna.

There is a condenser action between the ground post on the B current supply and the lighting circuit. This makes the electric light wires act as an antenna system, which, with the regular ground connection, makes an efficient collector of energy.

Theory

In Fig. 1 the proper position for a lightning arrestor is shown. It is placed where it can do the most harm to the small amount of energy flowing in the antenna circuit, and where it can protect the apparatus in case an excessive amount is present. Each arrestor possesses resistance, capacity and inductance. If the resistance is very low the receiving set is short circuited. The presence of inductance and capacity affects reception in a peculiar manner, depending on the frequency of the signal. Neglecting resistance for the moment we will set up the equations for a receiving circuit with and without the arrestor.

According to Fig. 2 X'_A is the reactance of the antenna itself. It is composed of the inductive reactance of the antenna in series with its condensive reactance. Mathematically

$$X'_A = \omega L_A - \frac{1}{\omega C_A}$$

where

$$\omega = 6.28\ f$$

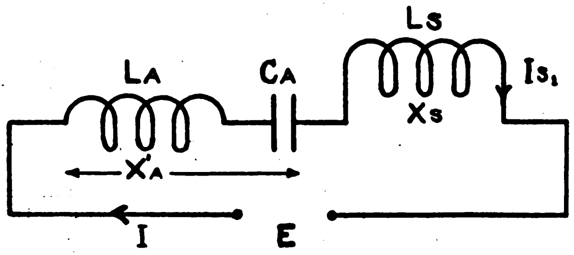


Fig. 2.

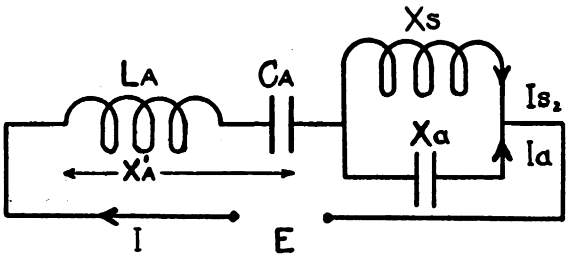


Fig. 3.

L_A is the antenna inductance and C_A is its capacity. f is the frequency of the signal being received. The reactance of the tuning element of the receiving set is X_S. The set may be either tuned or untuned in the antenna circuit. Let E be the voltage induced in the system by the transmitted wave. I is the total current in the antenna and I_{S1} is the part of this current which flows through the primary circuit of the receiving set. It is this current which must be kept a maximum in order to have strong signals in the set.

We may then write

$$E = (X'_A + X_S)\, I_{S1} \tag{1}$$

Note that $I = I_{S1}$.

Now let us insert an arrestor as shown in Fig. 3. We will show it as a capacity because its inductance is negligible. Let the total reactance of the arrestor be X_a. It is in parallel with X_s, hence the total reactance at the tuning element is

$$\frac{X_s X_a}{X_s + X_a}$$

This latter reactance is in series with the antenna reactance. Assuming that the induced voltage E is unchanged, we may write

$$E = (X'_A + \frac{X_s X_a}{X_s + X_a})I \tag{2}$$

The total current I is now made up of two components. One current I_{s2} flows through the receiving set and the other current I_a flows through the arrestor. That is $I = I_{s2} + I_a$. Making use of the fact that the voltage across the receiving set must be the same as that across the arrestor we may write $X_s I_{s2} = X_a I_a$ or

$$I_a = \frac{X_s}{X_a} I_{s2}$$

Hence

$$I = I_{s2} + \frac{X_s}{X_a} I_{s2}$$

Substituting this value of I in equation 2 we have

$$E = (X'_A + \frac{X_s X_a}{X_s + X_a})(\frac{X_a + X_s}{X_a}) I_{s2} \tag{3}$$

Since the induced voltages are assumed to be equal we can equate 1 and 3 and solve for the ratio

$$\frac{I_{s1}}{I_{s2}}$$

This is the ratio of the current in the receiving set without an arrestor to the current in the receiving set with an arrestor.

$$\frac{I_{s1}}{I_{s2}} = 1 + \frac{X'_A X_s}{(X'_A + X_s)X_a} \text{ or } 1 + \frac{X}{X_a} \qquad (4)$$

where $X = \frac{X'_A + X_s}{X'_A X_s}$

Equation 4 shows three very interesting facts. If X_a is condensive reactance, that is negative, and X is positive or inductive, equation 4 becomes

$$\frac{I_{s1}}{I_{s2}} = 1 - \frac{X}{X_a}$$

In words, this states that the current through the set without the arrestor is less than that through the set with the arrestor. But if X is also condensive when X_a is condensive

$$\frac{I_{s1}}{I_{s2}} = 1 + \frac{X}{X_a}$$

The current through the set without the arrestor is greater than that through the set with the arrestor. Furthermore, if the receiving set is tuned in some way then at resonance X is zero because X_s is zero and the arrestor has no effect on the energy received. Whether or not the arrestor will have any effect on signal strength is indicated by the antenna constants and the type of receiving circuit used. A tuned primary circuit will not be affected. But a large portion of the ready-made sets on the market are not tuned, and these will be affected to some degree by the arrestor.

Up to this point we have neglected resistance in order to simplify our calculations. If this resistance is small in comparison with the resistance of the receiving coil, the arrestor will act as a short circuit and will bypass a large portion of the antenna current. Conversely, if the resistance is relatively large, the arrestor will not have much effect on the circuit.

It is scarcely feasible to determine the resistances of the many types of circuits in common use, because the resistance is very low, so that a knowledge of the resistance of an arrestor is of little value. However, the reactances of many of the modern aperiodic circuits are easily determined, hence a knowledge of the capacities of the various types of arrestors is valuable. If we calculate the reactance of an arrestor at various frequencies and substitute this value in equation 4 we can

predetermine exactly what effect this particular arrestor will have on the receiving system. In order to determine the influence of the resistance of the arrestor on the system we will construct a typical circuit and actually measure the loss and compare the magnitude of this loss with that produced by the capacity effect of the arrestor.

Before considering these effects let us study the mechanical design of the arrestor. They grouped themselves into two distinct classes. First are those which must be protected from moisture and dust. The electrodes are either directly open to the atmosphere or are enclosed in a removable, perforated cap. Many of the arrestors are in this class. The electrodes must of necessity be very close together to permit arc-over at the required voltage. Any foreign particle coming between the electrodes will short circuit them and destroy the receiving range of the set to which they are connected. In several arrestors the electrodes consisted of two carbon blocks separated by a very thin layer of mica. A small carbon particle or even a drop of water short circuited the electrodes. Such arrestors must not be used out of doors unless made waterproof nor must they be used where dust will accumulate on them.

The second group of arrestors is composed of those which may be used out of doors. These fell into three distinct groups. One class used carbon electrodes, separated by mica but were sealed in a porcelain container. In these there is still the danger of a short circuit from particles of carbon. The second class used brass electrodes sealed either in a bakelite or a glass tube containing air. In these there is no danger from a short circuit, unless mechanically defective. The third class is composed of vacuum type arrestors. In the common form the vacuum type consists of two electrodes, sealed in a vacuum tube. The electrodes form a needle gap more widely separated than in the other types of arrestors. This seems to be the best type because there is less danger from short circuits and the resistance is rather high. However, there is one danger worth noting. If air leaks into the tube, the arc-over voltages are raised and they do not form good protectors. The chief difficulty with this type is in the fact that it is not easy to maintain a good vacuum.

The results of the test will be published in our next issue. A table of the capacities of the arrestors and typical curves of equation 4 will be given, showing the variation of the current ratio with frequency.

CHAPTER FOUR

FUNDAMENTAL PRINCIPLES OF RADIO

It is a mistake to suppose that radio must remain a mystery because it operates through invisible electrical actions. It is easily possible to obtain an insight into the underlying processes. They are much less complicated than the mechanism of an automobile. The reader who is interested in the explanation of radio will be well repaid by perusing this chapter, especially because it gives him an introduction to electrical principles in general.

The thing about radio that seems mysterious and complicated is, of course, the lack of connecting wires between the place from which the message is transmitted and where it is received. This mystery begins to disappear when we think of some similar happenings. Sounding a certain note in a room will sometimes cause a string in a piano on the other side of the room to resound. Consider another case. Suppose you are watching a chip floating near the edge of a quiet pond. If someone drops a stone in the middle of the pond, the water ripples spread out in rings and soon the chip is bobbing up and down. This is very much indeed like radio. The stone corresponds to the transmitting station, the chip is the receiving station, and the ripples correspond to the electric waves which constitute radio.

As will be explained later, the radio waves are produced by electric current in the transmitting station and at the receiving station they are converted into electric current again. So, after all, we really have to deal with electric current, both at the transmitting and the receiving end. Understanding of radio and ability to work with it boils down to understanding of electric current. We, therefore, consider for a while some of the fundamental facts about electric currents and ordinary electricity, and return after that to an explanation of the radio waves in the air between the transmitting and receiving stations.

Electric Current.—When a battery is connected to a metal wire, a something called an electric current flows in the wire. Like anything else, the electric current is useful because of the effect it produces. The two principal effects produced by electric current,

through which it serves mankind, are (1) the heating effect and (2) the magnetic effect. Whenever current flows in a wire it heats it somewhat; this is the basis of electric heating devices and the incandescent lights in our homes. If a very small magnet is brought near a wire in which a current flows the magnet will be deflected; that is, there is a magnetic effect produced near the wire. This is the basis of action of all dynamos and motors, of most electrical machinery, and (as we shall see later) of radio.

In order to have an electric current there must always be a closed "circuit," or path which returns into itself. An electric lamp or any other ordinary electric device is merely a part of this path, and connections must be made so the current can flow up to and away from the device. The path along which the current flows to and away from the electric device must be of conducting material, and is usually a pair

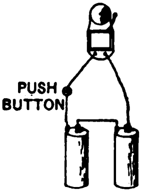


Fig. 1—Simple electric circuit.

of copper wires. For example, when connecting an electric bell, a wire is carried from one terminal of the battery (Fig. 1) to one of the terminals of the bell, and a second wire is brought from the other terminal of the bell back to the remaining terminal of the battery. Any break in the wire immediately causes the current to stop and the bell to be silent. This furnishes an easy method of controlling the ringing of the bell, since it is only necessary to break the wire at one point to stop the current, or to connect across the gap with a piece of metal to start the current going again. Thus we have the button for accomplishing the act of control, and the battery supplies the power required to ring the bell.

Similarly when we are using the city lighting circuit. Wires are brought more or less directly from the power-house to the electric lamp, and a small break in the path through the socket is provided. This can be bridged by a metal spring operated by the key. Sometimes the lamps suddenly go out, and we say that a fuse has been blown. A short length of wire, through which the current has been passing, is of an easily fusible metal which has melted away because too strong a current has been passing. Sometimes the lamps go out because it has become neces-

sary to open a switch at the power-house. It makes absolutely no difference where the break is made in the circuit, the result is the same; the current suddenly stops. Electricity is flowing in every part of the circuit, leaving the battery or dynamo at one side, and coming back to it at the other side.

A useful illustration of the electric circuit is a closed circuit of pipe (Fig. 2) completely filled with water, and provided with a pump, to circulate the water. Electricity behaves in the electric circuit much like an incompressible liquid in a pipe line. We are very sure that electricity is not like any material substance which we know, but the common practice among students and shop men of calling it "juice" shows that they think of it as like a liquid. It is convenient to consider the electric current to be a stream of electricity flowing through the wires. One way of measuring the rapidity with which water is flowing is to let it pass through a meter which registers the total number of quarts or gallons which pass through. By dividing the quantity by the time it has taken to pass we obtain the rapidity of flow. There are instruments by means of which it is possible to measure the total

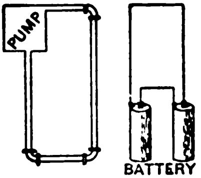


Fig. 2—An electric circuit is like a pipe circuit full of water.

quantity of electricity which passes any point in the circuit during a certain time. If we divide this quantity by the time, we obtain the amount of electricity which has passed in one second; that is, the current. In practical work, however, the current is measured by an instrument called an ammeter, which shows at each moment just how strong the current is, in somewhat the same manner as we may estimate the swiftness of a stream by watching a chip on the surface. This kind of an instrument enables us to tell at a glance what the current is, without the necessity for a long experiment. In this connection it will be remembered that two measuring instruments are to be found on an automobile. The speedometer shows what the speed of the car is at each moment, so that the driver may know instantly whether he is exceeding the speed limit, and govern himself as he sees fit. Another dial shows how many miles have been covered on the trip, and of course the average speed may be

calculated from its indications, if the length of the trip has been timed. The instrument for measuring total quantity of electricity corresponds to the recorder of the total miles traversed; the ammeter corresponds to the speedometer. The ammeter measures the current in a unit called the ampere.

Voltage (Electrical Pressure).—The water will not flow in the pipe line, Fig. 2, unless there is some force pushing it along, such as the pump, and it cannot be kept flowing without keeping up the pressure. Electricity will not flow in a circuit unless there is a battery or other source of electricity in the circuit. The battery is for the purpose of providing an electric pressure. This electric sort of pressure is called voltage. The larger the number of cells which are joined in the circuit the greater the electric pressure and the larger the current produced, just as the rapidity of flow of the water in the pipe line may be increased by increasing the pump pressure. The unit of voltage is the volt, and voltages are measured by an instrument called a voltmeter. The usual city lighting circuits have a voltage of 110 volts, and one cell of a lead storage battery gives two volts.

Resistance.—There is always some friction or resistance in a pipe whatever its size or material, and this hinders the flow of the water to some extent. Similarly there is something like friction in an electric circuit, which is called resistance. The greater the resistance the smaller the current which can be produced in the circuit by a given battery, just as the greater the friction the less rapid the flow of water with a given pump acting.

The unit of resistance is called the "ohm." The current in amperes is equal to the voltage in volts divided by the resistance in ohms.

Friction of any kind causes heat. Electric resistance is similar to frictional resistance, and heat is produced in the conductor which has the resistance. It is not friction of the ordinary kind, but is simply like it in that heat is produced. Just as for the flow of water in a pipe line, the amount of resistance is greater the longer the conductor and is also greater the smaller the cross-section. The resistance, and therefore the amount of heat produced in the conductor by a given current, depend also on the kind of material in the conductor.

Direct and Alternating Current.—When a water pump keeps up a steady pressure the water in the pipe line flows steadily and continuously in the same direction. Just so electric batteries and certain dynamo machines cause a current which flows always in the same direction around the circuit. This kind of current is called direct current. Certain other kinds

of dynamo machines produce current which alternates in direction at some definite frequency; this is called alternating current. The usual frequency of lighting current is 60 per second; that is, the current flows first in one direction and then the other, repeating this 60 times each second. Radio makes use of currents alternating millions of times a second.

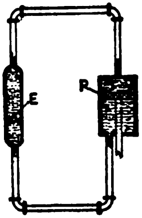


Fig. 3—Alternating water flow, analogous to alternating electric current.

Alternating current is like the sort of water flow that would be produced in a pipe line, if, instead of being acted on by a pump, the water were agitated by a solid piston P as in Fig. 3, which moved back and forth rapidly over a short distance. Under this impetus the water no sooner gets up speed in one direction than it is compelled to slow up and then gather speed in the opposite direction and so on over and over again. The water simply surges, first in one direction, and then in the other so that a small object suspended in the water would not travel continuously around the pipe line, but would simply oscillate back and forth over a short distance.

It is easy to tell whether an electric current is direct or alternating by using it to light a carbon-filament incandescent lamp and holding the lamp near a permanent magnet. If the hot filament is drawn to one side of the bulb and remains there, it is direct current. If the filament vibrates so that it seems to widen out into a bright band, the current is alternating.

Electric devices which depend for their operation on the heat produced by the electric current operate equally well on direct and alternating current. Devices, however, which make use of the magnetic effect of the current may behave very differently with direct and alternating current.

Condenser.—Suppose that an elastic partition E is arranged in the pipe (Fig. 3) so that no water can flow through or around it. If a pump P, or piston, acts steadily, the water moves a short distance until the partition is stretched enough to exert a back pressure on the water equal to the pressure of the pump, and then the movement of the water as a whole ceases. If, on the contrary, a reciprocating motion is given to

the water by P, the water moves back and forth, stretching the partition first in one direction and then in the other, and the water surges back and forth between short limits which are determined by the elasticity of the partition. We have an alternating current of water in spite of the presence of the partition.

An electric "condenser" acts somewhat like an elastic partition in a circuit. No direct current can flow through it, but an alternating current can. The electric condenser is not a conductor, direct current can not flow through it; it is a device which yields a certain amount, so to speak, when current tries to flow through it in either direction.

Perhaps a better way to understand a condenser is to think of it as similar to a gas tank used for the storage of gas. The amount of gas a tank will hold is not a constant fixed amount; it depends on the pressure. If the pressure is doubled, twice the amount of gas is forced into the tank. If the pressure is released and an opening is left in the tank, the gas rushes forth. Similarly, the amount of electricity that can be put into a condenser depends on the electrical pressure, called voltage. When the voltage is increased more electricity flows into the condenser, and when the voltage is diminished the electricity flows out again. By alternately increasing and diminishing the voltage, an alternating electric current flows in the condenser. Thus a condenser allows an alternating current to flow although it contains an insulating partition which prevents the steady flow of direct current.

Electric Energy and Power.—The flow of an electric current is accompanied by the flow of a certain amount of power. The capacity of anything to do work is called energy, and power is the rate at which energy is produced or the number of units of energy produced per second. The purpose of electrical apparatus is the transformation of the power of the current into other forms of power, heat, light and motion. The electric current is the means by which we transmit energy from the power-house to the consumer and we are not, for practical purposes, concerned with the method of carrying the energy any more than we need to inquire into the nature of the belt by which mechanical energy is carried from one wheel to another, or into the chemical nature of the water which is furnishing the power in a hydraulic plant.

The electric current itself cannot be seen, felt, smelt, heard or tasted. Its presence can be detected only by its effects—that is, by what happens when it gives up some of its power, as for example causing a motor to turn. Electrical power is given up, and mechanical power takes its place. Similarly, electric power may be used up and heat or light may appear

in its place. The electric lamp has an effect on the eye. We do not see the electric current in the lamp, but the effect on the eye is due to the light waves sent off by the hot filament. The power of the current has been changed over into heat in the lamp. When we hear a buzzing in the telephone, it is not the electric current we hear, but merely the vibration of the receiver diaphragm. The electric current has used some of the power in moving the diaphragm.

The power which is furnished by the electric current to any electrical apparatus depends both on the amount of the current and the voltage (electric pressure). The power is the product of the two. The product of current in amperes, by voltage in volts gives power in watts. For example, an electric flatiron takes about 5 amperes at 110 volts, so the power which it uses is 550 watts. Another unit of power that is commonly used is the kilowatt, which is simply 1000 watts. Thus, 750 watts is three-quarters of a kilowatt, this is about one horse-power.

The cost of electric service is in proportion to the energy supplied. The energy is the product of the power and the time and it is measured in kilowatt-hours. Thus, if an electric motor uses 2 kilowatts of power, the energy which it uses in 8 hours would be 16 kilowatt-hours. The electric companies that furnish electric current base their charges on the number of kilowatt-hours used. Electric meters give the number of kilowatt-hours used. How to read an electric meter, and how to test the meter, are explained in "Measurements for the Household," Bureau of Standards Circular No. 55, pages 84 to 90. Can be obtained from the Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 45c.

A little study of the following table may assist the reader to understand the units in which electric power and energy, are expressed. The way electric current furnishes power is similar to the flow of water through a pipe system at some point of which a water motor is placed. The power supplied to make this water motor turn and perform work would depend both on the flow of water through it and the pressure acting between the inlet and the outlet of the water motor.

	Water	Electricity
Rate of flow is measured in	Gallons per sec.	amperes
Pressure is measured in...	Lbs per sq. in	volts
Power is measured in....	Horsepower....	watts or kilowatts.
Energy is measured in....	Horsepower-hrs	kilowatt-hours

Sources of Electric Power.—The electric power used in everyday life comes from either of two sources.

These are: (a) dynamos, which operate by means of the magnetic effect of electric current; (b) batteries of chemical cells.

Dynamos will not be discussed here. Suffice it to say that the power furnished by the ordinary house wiring is supplied by dynamos at the electric power house. A complete description and explanation of the dynamos and motors useful in radio is given in "The Principles Underlying Radio Communication," Chapter 2. (See note, page 7, Chap. 3).

The production of electricity by chemical means was discovered in 1786, long before the magnetic effect of the electric current was known. For many years batteries were the only source of electric current, and the cost of producing electric power was very high. In fact it was thought that electric power would never be a commercial possibility, until after Faraday's discovery in 1831 that an electric current is produced by the motion of a wire near a magnet. This discovery made possible the invention of the dynamo. At the present time the amount of electrical energy produced by dynamos is millions of times that produced by batteries.

Batteries.—Although the cost of electrical energy is very great when obtained from batteries, yet it is often advantageous to use them. There are many cases where supply from a dynamo is not available, or batteries are more convenient, as for example, in portable lamps, door bells, and portable radio sets. A battery consists of a number of units called voltaic cells, or simply cells. A cell is a combination of chemicals with two metal terminals. When the terminals are connected by a wire a current flows in the wire, the electrical energy coming from the chemical energy inside the cell.

Among the most commonly used batteries are so-called dry batteries. These are not really dry, but are filled with a material which is moistened with the active solution and then sealed. One terminal is a carbon rod, while sheet zinc forms the containing vessel. This type of cell is made in a variety of shapes and sizes and is now used in large quantities, for use in flashlights, vehicles and all sorts of portable devices as well as radio receiving sets. Attempts are sometimes made to increase the life of dry cells by making a hole in the top and adding water, and also by recharging them electrically like storage cells; but the gain is very slight and seldom worth the trouble.

Storage Batteries.—Dry batteries depend for their operation entirely upon the chemical energy contained in the materials of which they are constructed, and when the cells are exhausted the materials have to be replenished or new cells purchased. In distinction

from such cells are storage cells. These do not contain any available energy, to start out with, but this energy is supplied by passing an electric current through them. This operation is called charging. After being so treated, current can be drawn from them. The process of drawing a current from the battery is called discharging.

The energy which is stored in the cell by the charging process would be stated in watt-hours or kilowatt-hours, like any electrical energy. As already explained, electrical energy in watt-hours is the product of the voltage in volts, the current in amperes, and the time in hours. The last two of these factors taken together, *i. e.*, the current multiplied by the time, gives the quantity of electricity that is put into the cell in the process of charging or converting electrical energy into chemical energy in the cell. The quantity is expressed in ampere-hours. Battery manufacturers have gotten into the habit of rating storage batteries by the number of ampere-hours used in charging.

Only two types of storage cells have proved to be commercially successful. The more common type, called the "lead" storage cell consists of lead plates, the surface of which have been specially treated with lead oxides, immersed in a dilute solution of sulphuric acid. It gives a voltage varying from 2.0 down to 1.75 when discharged. The Edison storage cell has nickel and nickel-iron for the plates, and the solution is an alkali. It gives a voltage varying from 1.4 down to 1.0 volt when discharged.

The filaments of electron tubes, when not operated from the house wiring, are lighted by storage batteries. All electric automobiles are operated by storage batteries. All automobiles having an electric starting equipment, also, have a storage battery to operate the starting motor.

For a more complete discussion of batteries, see "The Principles Underlying Radio Communication," Chapter 1, Section D. (See note, page 7, Chap. 3).

Magnetic Effect of Current.—One of the principal reasons why electricity has revolutionized the everyday life of mankind is that it may be utilized to produce motion. This simple principle makes possible the operation of telegraph and telephone, electric bells, electric motors, elevators and street-cars. The electric motor is also the backbone of many labor-saving devices used in the home, such as the vacuum cleaner, washing machine, electric fan, pump and sewing machine.

The reason that an electric current can cause motion is that every electric current is surrounded by a magnetic field. This is simply shown by the fact that any iron which is near an electric current becomes magnetized and tends to move. The motion of the iron may

be back and forth, as in the telegraph, telephone, or electric bell, or it may be round and round as in a motor.

In an electric bell, the electric current produces a magnetic action which causes motion of an iron piece, then the current is interrupted and the iron piece allowed to fall back to its former position, and then the whole process is repeated over and over. The way in which this is accomplished in the electric bell may be seen from Fig. 4. The contact C is interrupted when the iron piece I is attracted, because of current flowing in the wire. The interruption of the contact stops the current from flowing, the iron piece springs back and makes the contact again, and so the process repeats itself.

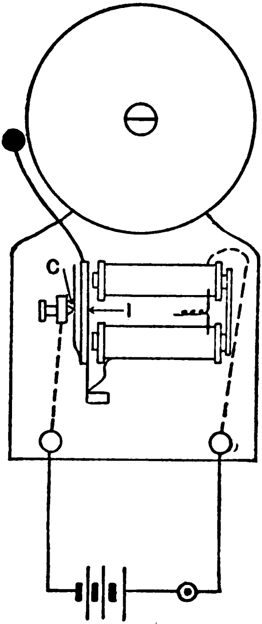


Fig. 4—Electric bell.

Besides causing iron to move, the magnetic field which every electric current produces is responsible for many other important effects. Whenever a magnetic field changes, it tends to produce an electric current in any conductor nearby. Thus a changing electric current causes a changing magnetic field and this in turn causes another electric current in a different conductor. The changing magnetic fields produced by varying electric currents are what make radio possible.

Production of Radio Waves.—Wherever there is an electric circuit in which alternating current is flowing, a magnetic field around the wire is constantly being produced and varied as the current in the wire varies. This magnetic field spreads farther and farther out, giving rise to an electric wave, just as a sound wave starts out from a vibrating bell or tuning fork. A powerful sound can be produced by using a very large tuning fork, and similarly a powerful electric wave is produced by making some part of the electric circuit large in dimensions. This enlarged part of the circuit is called the antenna. The antennas used in radio work, as is well known, often consist of long conductors supported on very high towers. The mechanism for producing a radio wave, therefore, is simply an enlarged or extended portion of an electric circuit in which an alternating current is made to flow. In the space near the antenna, alternations of electric pressure and of magnetic field are produced, just as alternations of air pressure are produced around a tuning fork. At any instant the electrical condition of the space around an antenna which is sending out radio waves could be shown by a diagram such as Fig. 5. The arrow on the line extending between the antenna and ground indicates that the electric pressure at a particular moment is in the direction indicated. When the current changes in direction, the direction of this electric pressure will be reversed and the electric pressure already mentioned will have handed on its effect to the surrounding space. Thus the effect of an

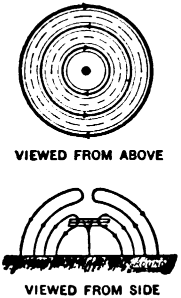


Fig. 5—Production of waves around an antenna.

electric pressure is handed on and spreads out through space, the direction of this pressure at any point is constantly alternating as the direction of the current in the antenna producing it alternates. The frequency of this alternation of the wave is the same as the frequency of alternation of the current in the antenna.

Lines of electric pressure alternating in direction are

thus constantly spreading out from the antenna just as the ripples spread out on a pond after a stone has been thrown into it. Something very similar to the ripples would be seen if, in some way, the alternations of electric pressure could be made visible and a person were to look down from above upon the antenna and the space around it. The waves of electric pressure spreading out and successively alternating in direction would look something like the lines shown in the upper part of Fig. 5. The waves spread out in all directions and go to great distances.

It at once suggests itself that the waves will produce an effect at a point far distant from the source if a means is provided at that point for converting the wave action into electric current in a circuit. In this way electric communication without connecting wires is established.

Nature of Radio Waves.—We cannot see electric waves, as we see ripples or the waves on a pond, but there is nothing specially mysterious about them. We can not see sound waves. If a tuning fork is struck, it gives off sound waves, which, starting at the tuning fork, travel out into the air in all directions like the ripples referred to. Sound waves are produced by the motion of the metal prong of the tuning fork. As the prong moves back and forth it causes the air next to it to move back and forth. This motion is handed on to the surrounding air and so moves out to a great distance in the air just as the ripple on the pond spreads out. The slight to-and-fro motion of the air spreading out in this manner is called a sound wave.

Electric waves also consist of a certain kind of to-and-fro motion. Just as the motion of the tuning fork causes alternating pressure in the surrounding air, similarly, whenever an alternating electric current flows in an electric circuit the to-and-fro motion of the current causes alternating electric pressure in the space next to the wire. This to-and-fro or alternating electric pressure in the space surrounding the wire affects the surrounding space and spreads out in exactly the same way as a sound wave in air.

The electric waves are also called radio waves, and it is by means of them that radio communication is carried on. It is an interesting fact that radio waves are really of the same kind as light waves. We are all familiar with light waves, and it should help to make radio waves less mysterious to know that they are both electric waves. The difference between light and radio waves is the frequency of alternation. Thus electric waves are much more common things than is sometimes supposed. Electric waves are used for many purposes, their use depending on the frequency of the waves. This is shown by the table on page 13

showing the frequencies of the various kinds of electric waves.

Wave Length and Frequency.—Frequency is the number of cycles per second, or the number of to-and-fro alternations of the electric pressure, as the wave travels out through space. Wave length is the distance from the crest of a wave to the crest of the next adjacent wave. Since all electric waves travel at the same velocity (186,000 miles per second, or 300,000,000 meters per second), the shorter the length of the waves the larger the number of them which will pass by a given point during a second. The length of the waves is numerically equal to their velocity divided by their frequency (number of cycles per second). That is,

$$\text{wave length in meters} = \frac{300{,}000{,}000}{\text{frequency}}$$

For example, a radio wave 600 meters long is caused by a current in a transmitting antenna having a frequency of 500,000 cycles per second.

Waves Produced by	Cycles per second
Commercial Alternating Currents	25 to 500
Ordinary Telephone Currents	16 to 3,000
Radio	10,000 to 30,000,000
Heat and Light	3,000,000,000,000 to 3,000,000,000,000,000
X-Rays	3,000,000,000,000,000,000

All of these waves travel at the same speed. These electric waves are of an entirely different nature from sound waves. Sound waves are not at all electrical; they consist of actual to-and-fro motions of the air particles and travel with a speed of about 1,000 feet per second. The speed at which electric waves travel is much greater than this; it is so great that the passage of any kind of electric wave is practically instantaneous. The various kinds of electric waves shown in the table are much alike in many ways but they have some characteristic differences. Thus, radio waves are different from light waves in that they go through ordinary walls of buildings and other obstacles which are opaque to light.

The waves are radiated and spread out more effectively the higher the frequency. The ordinary low frequencies used in the alternating currents which light our houses alternate very slowly. Such waves travel readily along wires. In order to get a wave which will travel effectively through space, higher frequences must be used; that is why the waves used in radio communication make a large number of vibrations per second.

It is to be noted that these frequencies are not, however, as high as the frequencies of light waves. Light waves travel in straight lines, which is one of their characteristic differences from low-frequency waves of alternating current power, which follow along wires. Radio waves are intermediate in character between the two, and can travel in straight lines and also travel along conducting wires.

The fact that radio waves, which are able to travel out into space without conducting wires, are of high frequency, is one of the important characteristics of radio communication.

Wave Reception.—Now think of what is happening at a distance from an antenna which is sending out waves. As the wave passes any point there is an alternation of electric pressure going on continuously at that point. The alternating electric pressure or wave action at that point could be illustrated by the wavy line of Fig. 6. The portions of the wave above the horizontal line correspond to the electric pressure in one direction, and the portions below correspond to

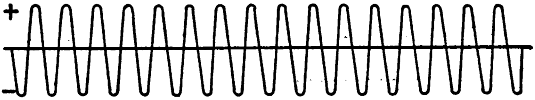


Fig. 6—Continuous wave.

the electric pressure in the other direction. This can be understood by thinking of a sound wave. As the sound wave passes out through the air, it will set in vibration any object which is capable of taking up the motion. Suppose, for instance, that a sound wave produced by a tuning fork passes a second tuning fork which is in tune with it, that is, having the same natural pitch or frequency of vibration as the first tuning fork. The to-and-fro motion of the air will start the second tuning fork into motion. This can be readily shown with two tuning forks, striking one of the forks, thus producing a sound wave. It can be proved that the second tuning fork is set into vibration by grasping the first with the hand so as to prevent its further motion. A sound from the second one can then be heard.

A radio wave can produce an effect at a distance in just the same manner. In any electric circuit the moving wave of electric pressure produces an electric current alternating with the same frequency as the wave. The moving wave is accompanied by a magnetic field, just as a current is. This moving magnetic field produces an electromotive force in any conductor across which it cuts, just as an electromotive force is produced by any other relative motion between a

conductor and a magnetic field. The electromotive force thus produced is what causes a current in the receiving antenna.

Comparison of Radio with Ordinary Wire Telegraphy or Telephony.—In the preceding sections the mechanism by which an electrical action can be made to affect a distant point without wire connection has been explained. The ether which fills all space can be considered to replace the wire connection. Thus, in wire communication there is a system as represented in Fig. 7, which shows a conducting wire line containing a source of varied current at one end and a detecting device (D) at the other end. In radio communication the wires are eliminated so that the corresponding simplified system would be as represented in Fig. 8, which shows the similar source of varied current and detecting device (D), each of these, however, being placed in a simple electrical circuit and the conducting wires between being eliminated. Both of these diagrams have been so greatly simplified that neither of them is really just like an actual telegraph or telephone system. Certain additional features must be used beyond what is shown in either Fig. 7 or Fig. 8 to carry on telegraphy or telephony. A species of telegraphy is possible by merely adding a key in either Fig. 7 or Fig. 8. Wire communication of this kind

Fig. 7—Wire communication.

would thus be the use of an alternating-current generator as the source of power and a telephone receiver as the detector (D). The corresponding radio system would be the use of an alternating-current generator of high but still audible frequency together with the use of a telephone receiver in place of detector D. As a matter of fact, simple systems of just this kind are not

Fig. 8—Radio communication.

used because great advantages are secured by the addition of certain features which will now be discussed. Furthermore, these additional features not only improve radio telegraphy but are necessary for radio telephony.

Tuning.—The extremely simple system of radio communication indicated in Fig. 8 is not effective un-

less the alternating current used is of high frequency. Even then the current produced in the receiving circuit would be very small indeed unless the receiving circuit is in tune with the wave. That is, it must be arranged to respond to the frequency of alternation possessed by the first circuit and the wave which it sends out. This is just like what happens with the two tuning forks and the sound wave. The second tuning fork does not respond to the wave from the first unless the two are in tune. This can be shown by placing a bit of wax on one of the prongs of the second tuning fork, changing the pitch of that fork. When the first tuning fork is struck under these conditions it can readily be demonstrated that the second fork does not respond. In the same way the electrical arrangements in the receiving circuit which are used to receive radio waves must be such that the receiving circuit is electrically in tune with the radio wave. By this means the radio receiving circuit can pick out the particular wave which it is desired to receive and not be affected by other waves. This is fortunate because otherwise the interference between different radio messages would be hopeless. It would be just as though every sound wave which passed through the air set absolutely everything which it touched into vibration.

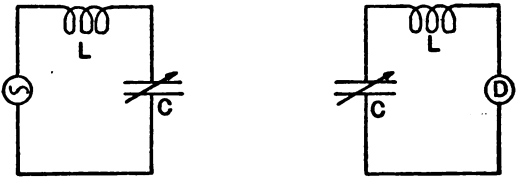


Fig. 9—Tuned radio circuits.

Just as the frequency to which a tuning fork responds depends upon its inertia or mass and its springiness or elasticity, the frequency to which the electrical circuit responds depends upon two corresponding electrical properties called inductance and capacity, respectively. The "inductance" is the electrical quality that corresponds to the inertia or mass of the tuning fork, and the "capacity" corresponds to its elasticity. The greatest current is produced in a receiving circuit when both the transmitting and receiving circuits are tuned—that is, arranged so that the product of the capacity and inductance is the same in each. The elements of a typical radio circuit are thus rather more complicated than shown in Fig. 8, which should be replaced by Fig. 9. The symbols C and L indicate the conventional diagrams for capacity and inductance. The device used to introduce capacity into a circuit is called a condenser, this usually consists of a pair, or two sets

of metal plates separated by air or by some solid non-conductor. The device used to introduce inductance into a circuit is called an inductor, or an inductance coil, or simply a coil; it is a coil of wire, as suggested by the usual diagram for an inductance.

Modulation.—We come now to a feature of radio which is often not understood. Anyone who will take the trouble to read this section ought, however, to gain a clear comprehension of the important subject of "modulation." As just mentioned, the frequency of alternation of radio waves is very high. It is so high, in fact, that a sound wave of such frequency could not be heard. Suppose, for instance, that an ordinary telephone receiver is used as a detector (D) in the circuit which is receiving a radio wave. Electric currents produced in a receiving circuit are of the same frequency as the wave frequency and tend to cause motions of the telephone receiver diaphragm. These motions are, however, of such great frequency that the diaphragm produces no audible sound. In order to permit the radio wave to be received and transformed into a sound, it is therefore necessary to break up the radio wave in some manner. This is done in radio telegraphy by interrupting the wave completely so

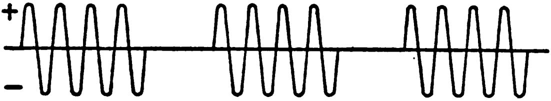


Fig. 10—Interrupted wave.

that it consists not of a single regular series of alternations but of a succession of groups of such alternations. That is, instead of the continuous wave shown in Fig. 6, it consists of the interrupted wave or group of waves illustrated in Fig. 10. The frequency of the interruptions or of the groups of waves is a frequency which is low enough to be heard. One of the ways of breaking the waves up into groups is by use of a "chopper," which is simply a rapidly rotating disc with contacts on it so as to alternately open and close the circuit.

This process of varying the high-frequency wave so that it is no longer a single regular series of alternations is called modulation.

Instead of breaking the wave up into simple groups of alternations, it is possible to modulate it,(*i. e.*, cause it to vary)in a manner which follows the sound variations produced by the human voice. It is thus possible to make a radio wave carry a voice wave. This is the process of radio telephony, and will be explained further in the next chapter.

Besides the reason given in a preceding section for the use of high frequency in radio, there is another

very powerful reason, which is connected with modulation. When it is desired to carry on telephony, it is necessary that the alternating current which produces the waves be of a frequency to which the sense of hearing does not respond. This is necessary because if the waves were of an audible frequency, the current which they produce in the receiving circuit would produce a sound that would be heard and would interfere with the voice or other sound which it was desired to hear. The wave frequency must therefore be so high that a sound wave of such frequency could not be heard.

Summary.—The principles of radio have been briefly explained in this chapter. They are few and simple. An electric wave is sent out into the air by means of electric current flowing in the transmitting antenna, the current being an alternating current of very high frequency. The high-frequency current (and consequently the wave it produces) is varied in accordance with the sound variations of the speech or other sound or signal which is to be transmitted, this process being called modulation. The radio wave spreads out in all directions, and can produce electric current in any electric circuit that is tuned to respond to the radio wave frequency. The way in which the current thus produced in radio receiving apparatus is converted back into sound is explained in the next chapter. The essentials of a complete radio transmitting and receiving system are shown in Fig. 11.

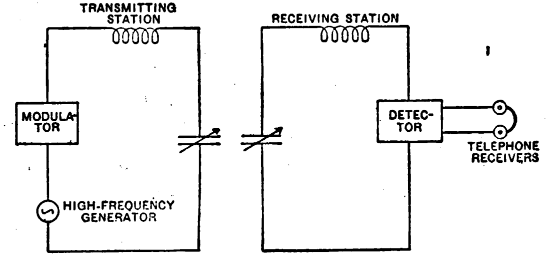


Fig. 11—Complete radio transmitting and receiving system.

MOTOR-GENERATORS FOR BATTERY CHARGING

The use of motor-generators for charging purposes is not very extensive. for as a rule the cost of these outfits is somewhat higher than the cost of a bulb or vibrating rectifier. They are used mostly in charging stations where great numbers of batteries are charged. They are more flexible in operation than bulb or vibrating rectifiers, and can be controlled at will without any trouble or inconvenience.

A motor-generator is simply a motor and a generator connected by a common shaft. The motor is driven by the 110 v. a-c supply and the generator delivers a d-c. voltage a little in excess of the voltage of the battery to be charged. The set operates at constant speed and the generator voltage can be varied by insertion of a rheostat in its field circuit.

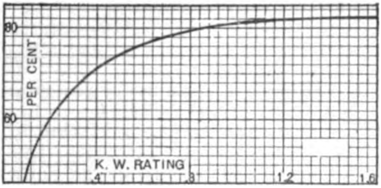


Fig. 1—Efficiencies of d-c machines for various power ratings

Fig. 1 gives the efficiencies for the line voltages in general use, that is, 110 or 220 volts. Similar efficiencies can be expected from generators delivering current at similar voltages. The efficiency of a d-c. generator is given by

$$\text{Eff} = \frac{VI}{VI + (K + RI^2)} = \frac{1}{1 + 1/V(K/I + RI)}$$

in which V is the delivered voltage, I the delivered current, R the armature resistance, and K the constant (core) losses. This equation shows that if we assume the constant losses in both 110 volt and 8 volt machines to be of the same order of magnitude, and we consider the case of equal values of current, the lower the voltage the lower the efficiency becomes; that is to say the larger the output power (VI) becomes in comparison with the losses ($K + RI^2$) the nearer we approach 100% in efficiency. It is to be expected, then, that the efficiency of machines delivering low voltages suitable for charging batteries will be considerably lower than indicated by Figure 1.

The efficiency of an 8 volt generator is about 89% of the efficiency of a 110 volt generator, assuming equal ratings and equal constant losses. Taking 500 watts as the full rated load of a typical M. G. set, figure 1

gives the efficiency of a 110 volt machine as 75%. The efficiency of the corresponding 8 volt machine is then in the neighborhood of $75 \times 89 = 67\%$. The overall efficiency of the unit is then $67 \times 75 = 45\%$. These efficiencies are merely nominal, and are given solely for the purpose of giving the reader a rough idea of their values.

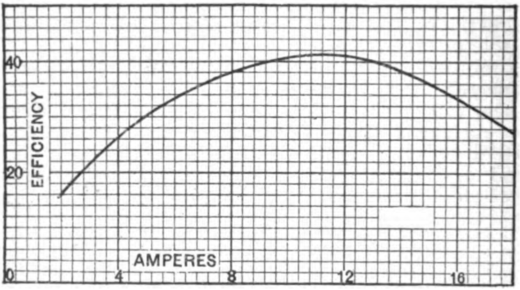


Fig. 2—Efficiency of small motor generator set for battery charging

Fig. 2 is a curve showing the variation of efficiency of a small motor-generator set with the delivered current. The maximum efficiency as shown by this curve is 41% which corresponds closely with the figure given above.

RECTIFIER vs. DETECTOR

Considerable confusion exists among many writers of articles dealing with the theory of electron tubes concerning the use of the words rectifier and detector. There is a great difference between the meanings of the two words, and the word rectifier should not be used in connection with all types of detectors.

The three-electrode vacuum tube used as a detector, if the grid potential is adjusted so that no current flows from the grid, does not act as a rectifier. It acts merely as a valve. Since no grid current flows, how can it be rectified? The trigger action of the grid merely allows current from the local source of energy (the "B" battery) to flow in the plate circuit.

The idea of rectification in a three-electrode tube must be confined to the grid current only. When the grid potential is positive, the grid current is allowed to flow. When it is negative, the grid current stops flowing.

The Fleming (two-electrode) and the crystal detector are rectifiers. When the voltage of the oscillations to be detected is in a certain direction, the current is allowed to flow, but when in the opposite direction, the current is either diminished or stopped entirely. These are both rectifiers and detectors.

POTENTIOMETERS

The diagram of Fig. 1 illustrates the principle of operation of potentiometers. A resistance AB is connected across the terminals of a battery, so that a current continually flows, producing a drop in potential along the resistance. The difference of potential between any two points on the resistor may be taken off as at A and a′ for any purpose which may require it, as will be explained below. In the example shown, the resistance is connected across a 6-volt battery, such as used for lighting the filaments of electron tubes. The total voltage drop across AB is equal to the voltage of the battery, i.e., 6 volts. This value is obtained when the movable contact has been moved to a_3. As the contact is moved in the direction from B to A, the voltage drop between A and the contact decreases from 6 volts to zero. For intermediate positions of the contact the voltage varies between 6 and zero volts. Thus, when the contact has moved over ⅓ of the resistance toward A, as at a_2, the voltage drop is 4 volts; when at a_1 it is 2 volts, and so on. In other words, the potential difference between A and the movable contact is proportional to the amount of resistance between them. When the contact has arrived at A, the voltage drop is zero, as there is no resistance between A and the contact at this setting. These are the principles involved in all potentiometers, but their applications are extremely varied.

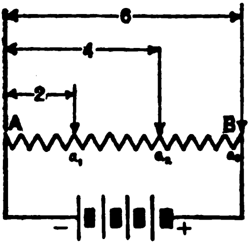


Fig. 1

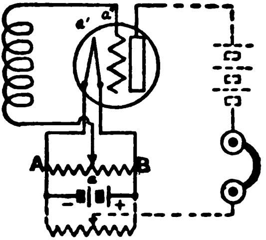


Fig. 2

Take the case of Fig. 2, which shows the application of potentiometer control to adjusting the grid potentials in electron tubes. AB is the resistor as before, and here the battery is also supplying the filament-heating current. This heating current is controlled by a rheostat in one of the leads to the filament, not shown. This rheostat does not affect the current through the potentiometer resistor, and is omitted for simplicity. When the moving contact a is midway between A and B, the potential of a is the same as that of the point a′ of the filament. The grid of the tube, shown at a″, has practically the same potential as a, neglecting the small

resistance drop through the tuning inductance, so that for this setting of the contact, the potential of the grid is zero with respect to the filament. (We are not considering the potentials acquired by the grid in accumulating electrons emitted by the filament.) However, the point of zero grid voltage will not be exactly midway between A and B when some of the filament rheostat is in the circuit. This complicates matters and does not add to the explanation, so it is omitted.

Now as a is moved to the right, a″ will become positive with respect to a′; if to the left, it will become negative with respect to a′. The grid-filament voltage can thus be easily and accurately controlled by this method.

The same method can be used to control the voltage on the plate of the tube, as is indicated by the addition of another potentiometer, shown in broken lines in Fig. 2. As a rule, the tubes on the market do not require accurate adjustment of the plate voltages, and adjustment of this voltage is not vital to satisfactory operation of the set. However, if the experimenter wishes to have accurate control of both voltages, he may use this arrangement.

Fig. 3 shows another method of controlling the grid bias. This arrangement accomplishes not only the same effects as the usual "C" battery, but does it more accurately and effectively. The potentiometer may be placed in the lead to the filament, if preferred.

There are many makes of potentiometers on the market, and the amateur must be careful in picking out the one best suited to his purpose.

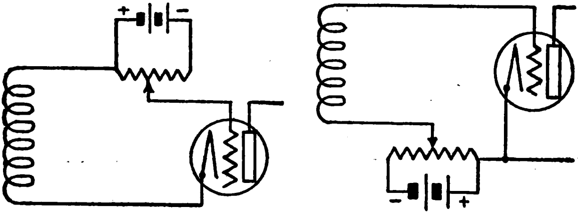


Fig. 3

The resistance generally consists of a wire wound on a form. This wire must not be too fine, as continual rubbing of the moving contact will cut the wire. At the same time, the resistance must be sufficiently high to prevent an excessive drain of current from the battery. It will be noticed that there is a constant current from the battery flowing through the resistor. When the set is not in use, the battery should be disconnected from the potentiometer. The value of this current is obtained by dividing the resistance of the potentiometer into the voltage of the battery.

PROPERTIES OF CONDENSERS

(Continued from April issue)

Dielectric Absorption

In the last issue of Radiofax an explanation of power-factor or phase-angle, and dielectric absorption was given. Although not very important in the case of variable air condensers, dielectric absorption plays an important part in condensers with solid dielectrics, such as mica or waxed paper. If a condenser with solid dielectric be repeatedly charged and discharged, the dielectric will be found to become warm, indicating a transformation of some of the energy into heat. The amount of heat generated is greater than the amount that can be accounted for by mere resistance losses, and this excess of heat is ascribed to the dielectric absorption of the condenser. If a series circuit containing a condenser with solid dielectric, and a source of voltage, be closed, a sudden rush of current will take place at the instant of closing of the circuit. This is the charging current, that is, the current that flows into the condenser by virtue of its capacity, and is given by the equation:

$$Q = CV,$$

in which Q is the quantity of electricity in coulombs or ampere-seconds, C is the capacity in farads and V the voltage in volts. The duration of this charging current is an exceedingly short period of time, perhaps a hundred-thousandth of a second.

However, in many cases it will be found that a current continues to flow for a long time after the circuit has been closed. The value of this current bears no simple relation to the capacity and voltage, and seems to depend entirely upon the nature of the dielectric used in the condenser. This is the absorption current. Attempts have been made to account for it by assuming that the substance of the dielectric is not a homogeneous mass and that there are tiny capacity effects between various points in it which gradually charge up, thus continuing the current flow.

Equivalent Resistance

Obviously this represents a loss of power, since it takes energy to charge these tiny condensers, and they are not located at positions where they will do any good. In order to account for this absorption, dielectric absorption is spoken of as an "equivalent resistance" in series with the condenser, or at least its effect can be measured as if it were a series resistance.

Effect of Frequency on the Absorption

It is evident that the quantity of electricity which flows into an absorbing condenser is greater the greater the charging period. Some very poor condensers have been known to absorb a continually decreasing charge for several days, on a direct current charge. With

alternating currents, charge and discharge takes place in every cycle, and the amount of charge that can be absorbed, since it depends on the charging period, also depends on the frequency of the current, since the frequency is the reciprocal of the period. The higher the frequency, the shorter the charging period, hence the smaller the absorbed charge. At infinite frequencies, then, the charging period would be infinitesimal and no absorption would take place. The capacity of the condenser as measured at infinite frequency is called the "geometric capacity" and is the capacity that could be calculated from the geometric dimensions of the condenser if we could measure these accurately. As measured at any other frequency, the absorbing condenser has an apparent capacity which is higher than the geometric capacity.

Reducing the Absorption

The method of reducing the absorption in condensers is obvious. If a solid dielectric must be used, the one chosen should have little absorptive effects. In air condensers, insulating material is needed at certain points in the construction to support the movable and fixed plates. The amount of dielectric between these points should be as small as possible. The cost involved in the manufacture often makes it impossible to take care of these points, and it will generally be found that the cheaper condensers show greater absorption and resistances than the higher priced and consequently better designed condensers. Paper condensers show considerably more absorption than mica condensers, and mica condensers show more absorption than air condensers. In fact, in many cases it is next to impossible to measure the power-factor of air condensers unless their construction is extremely poor.

Series Resistances

There are other series resistances present in condensers which cause a loss in power. These are the resistances of the plates themselves and the resistances of the leads and constants. In many variable air condensers, contact is from one of the binding posts to the movable plates by means of a wiping or sliding contact. This does not represent the best design, as there is a resistance in this contact which may be eliminated by the use of a pig-tailed connection, as it is called. This is merely a flexible connector coiled in such a manner that the rotation of the shaft to which it is attached does not cause it to kink and break off.

To reduce the resistance of the plates it is necessary for the designer to use metals of high conductivity, such as brass. Copper is generally too soft and is liable to bend, causing contact between the plates. For purposes of rigidity it is necessary that these plates be as thick as possible.

CALCULATIONS OF THE SECONDARY CIRCUIT

In the October issue of Radiofax we have shown how to determine the various constants of the antenna circuit. In the November issue it was shown how to calculate the frequency and wave-length of the circuit and its range. In this article we will carry the discussion on into the secondary, showing how to obtain the proper values of inductance and capacity required for resonance, and also go into the discussion of inductive coupling.

In all cases where a circuit is to be tuned to a certain frequency or wave-length, the oscillation constant, which is the product of the inductance and capacity in series in that circuit, has a certain definite value. The relation between these quantities is the old formula $f = 159.3 \div \sqrt{LC}$, in which L, the inductance, is in microhenries and C, the capacity, is in microfarads. The frequency, f, is in kilocycles per second. Since the secondary circuit is to be tuned to the same frequency as the primary, the oscillation constant in both these circuits must be equal. Let us represent this by LC. If we happen to know the value of either L or C, the other can be immediately calculated by dividing the one we know into the oscillation constant.

This calculation is eliminated, however, by the use of Fig. 2, which shows the relation between the inductance, capacity and frequency in a series circuit. Referring to Fig. 1, the antenna circuit is coupled to the secondary circuit through the variocoupler. The coupling in the ordinary receiving circuit is so loose that we can neglect the effect of the mutual inductance between the primary and secondary windings.

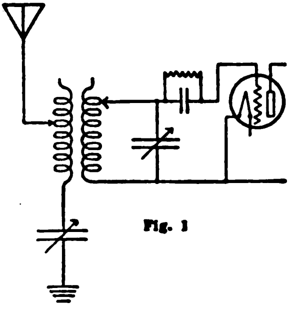


Fig. 1

Let us take the case of the single-wire antenna with variocoupler and without loading coil, described in the November issue. The wave-length was found to be 800 meters and the frequency 375 kilocycles per second. The oscillation constant is 0.179. The self-inductance of the secondary winding of the variocoupler is taken approximately as 415 μh. The capacity required in the secondary circuit is, then, $0.179/415 = 0.00043$ μf. The nearest size variable condenser to this on the market is the so-called 23-plate condenser, which has a maximum rated capacity of 0.0005 μf.

The value of the capacity required may be read directly from the curves in Fig. 2. These curves have been

constructed for the condensers available, viz., 0.001 and 0.0005 μf. It is noticed that the intersection of the broken lines drawn from the 800-meter division for the wave-length and from the 415 μh division for the inductance, lies in the vicinity of the curve for the 0.0005 μf condenser. Fig. 2 cannot be used for the antenna circuit calculations.

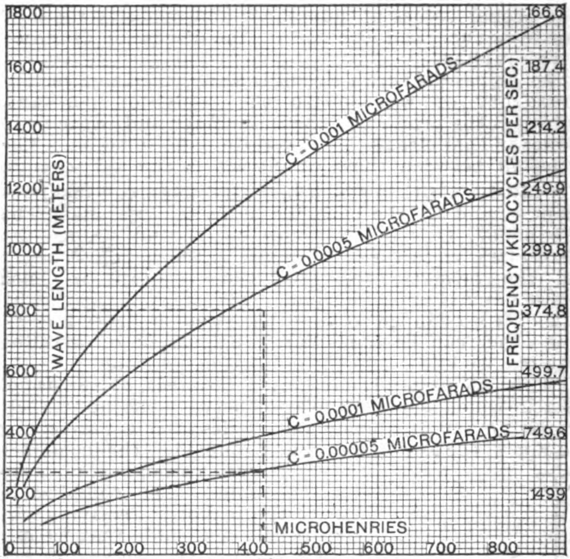


Fig. 2

Variable condensers all have minimum values of capacity; that is, the capacity is not zero when the reading on the condenser dial is zero. We have assumed in this case that the minimum capacity of the 0.0005 condenser is 0.00005 μf. The dotted line on the chart immediately shows that the lowest wave-length this combination of variocoupler and condenser will tune to is 270 meters. This value can be arrived at by using the formula $\lambda = 1884\sqrt{LC}$, in which L is 415 μh and C is 0.00005 μf. Similar curves are drawn on the chart for the 0.001 μf condenser. These two condensers are generally known as the 23- and 43-plate condensers.

The results obtained in the calculations above are approximate, as some constants present in the circuit have been neglected, as for instance, the capacity of the grid condenser and that between the grid and filament of the vacuum tube. The capacity between the tube electrodes is very small, however, compared to the other capacity in the circuit, being in the neighborhood of 10

$\mu\mu f$, and the same may be said of the grid condenser capacity, which is generally about 0.00025 μf. The joint capacity of these two in series is only about 9.5 $\mu\mu f$, so that the effect on the capacity of the whole circuit is small. The results obtained in these calculations are sufficiently accurate for ordinary design of radio receiving sets.

Coupling. In the analysis of coupled circuits it is found that when the primary and secondary circuits are tuned alike, currents of two frequencies are set up, which frequencies are given by

$$f' = \frac{f}{\sqrt{1+k}} \quad \text{and} \quad f'' = \frac{f}{\sqrt{1-k}}$$

in which f' and f'' are the two frequencies in question; f is the frequency to which the two circuits are tuned (that is, the natural frequency of the circuits), and k is the coefficient of coupling. This latter is a quantity that also arises in the theory, and is given by

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

for the simple circuit described here, in which M is the mutual inductance between the primary and secondary circuits, and L_1 and L_2 are the self-inductances in the two circuits.

The mutual inductance of the variocoupler in this case we will take as equal to 250 μh. The self-inductances of the primary and secondary of the variocouplers are 415 μh each, and the total inductance of the antenna is 33 μh. Using the equation above, the coefficient of coupling is,

$$k = \frac{250}{\sqrt{(415 + 33) \times 415}} \times 100 = 57.8\%$$

This is the value of the coupling, expressed in per cent, when the coupling is as close as possible, that is, when the axes of the primary and secondary coils of the variocoupler coincide. The natural frequency to which the circuits are tuned is 375 kilocycles (800 meters). By inserting this value of coupling in the formulas above for the two frequencies, expressing the coupling coefficient as a decimal, we obtain,

$f'' = 299$ kilocycles (1000 meters);
$f' = 577$ kilocycles (520 meters).

The power of the incoming signals is therefore distributed between these two frequencies, so that maximum results could not be obtained by tuning the circuits to either frequency. This illustrates the desirability of employing loose coupling. The equations giving the two frequencies show that when the coupling coefficient becomes smaller and smaller the two frequencies become more nearly equal, until when the two coils of the

variocoupler are at right angles, and the coefficient equal to zero, the two frequencies are equal to each other and the natural frequency of the circuits. Figure 3 shows the variation of the two frequencies as the coupling is varied from a maximum (in this case 57.8%) to zero.

The student must note that the coefficient of coupling can be changed without changing the value of M. If L_1 or L_2 are increased, k will increase. The coupling is a function of the total inductance in the circuits, not of the mutual inductance alone.

As the coefficient of coupling becomes smaller, the two waves approach each other in their frequency values. This phenomenon is generally unnoticed in receiving sets, where the coupling is as a rule very loose, but in transmitting sets the coupling must be sufficiently loose that only one perceptible wave is radiated. If this is the case, then we have a sharp wave. If not, then it is a broad wave.

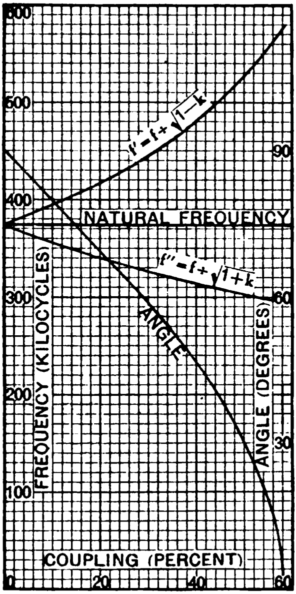


Fig. 3

The curves have been calculated for the case of maximum mutual inductance in the circuit. As the angle between the two coils of the variocoupler increases, this mutual inductance increases, so that the coefficient of coupling decreases. If the coupling was loose to begin with, this change in coupling will not produce very appreciable change in the wave-length; if it is close, however, a loosening of the coupling will increase the wave-length, so that the loosening of the coupling must be compensated by a decrease in capacity of the secondary condenser and a decrease in inductance or series capacity in the antenna circuit. The value of the mutual inductance for any setting of the variocoupler is given by M cos θ, in which M is the maximum value and θ is the angle between the axes of the primary and secondary coils. The values of the coefficient of coupling for different settings of the rotor of the variocoupler described above are shown in Figure 3. This relation is approximate only.

ELECTROLYTIC RECTIFIERS

The fact that certain metals, when immersed in a variety of electrolytes, permitted current to pass in one direction but not in the other direction, has been known for a great many years, and for the past twenty years more or less constant efforts have been made to apply this phenomenon to the charging of storage batteries.

The principle involved in the case of all so-called valve metals may be explained by the formation of a gas film trapped in porous oxides on the surfaces of the metals, which acts as a dielectric to a greater or less extent when electron flow is from the solution into the valve metal, and which permits the passage of electrons from the valve metal into the solution with practically no interference.

Many metals in specific electrolytes and under limited electrical conditions show valve action to a slight degree. Among them may be listed magnesium, zinc, cadmium, zirconium and tungsten, tantalum and aluminum. Of these, aluminum and tantalum are the only ones which have shown valve action sufficiently satisfactory for commercial purposes.

The valve action of these electrolytic cells may be considered from the point of view of conduction of electricity through gases. The passage of electrons through gases takes place almost entirely in one direction. This direction of electron flow is from the cathode or negative electrode to the anode or positive electrode, resulting in a current flow whose direction is from anode to cathode.

The form of cell commonly used consists of a plate of aluminum and a plate of lead or carbon, immersed in a solution of ammonium phosphate or borate, dilute sulphuric acid or ordinary borax. Five or six theories have been proposed in attempting to explain the action of these cells. All of them are more or less evasive. The following is an outline of the one that is probably the best known.

Let us consider a cell of aluminum and lead plates in an electrolyte of dilute sulphuric acid. Also suppose the aluminum plate to be connected to the positive terminal of the source of electric energy. A very thin coating of aluminum oxide exists on the surface of the aluminum plate, which is a result of exposure to the oxygen of the air. While this coating is a rather poor conductor, it does not limit the current materially; and since it is so thin, when it is placed in the electrolyte some of the acid can leak through the pores of the oxide and attack the aluminum plate. This results in the formation of more of the oxide, the thickness of the coating becoming greater and at the same time, porous. The acid in solution is ionized and oxygen molecules are liberated which have negative charges. These

oxygen molecules are attracted to the positive aluminum plate, where they give up their electrons, and are evolved as neutral oxygen gas.

It has been said that the coating of aluminum oxide on the aluminum plate is very porous. Some of this oxygen gas, which possesses high electrical resistance, is held entrapped in the pores of this oxide, so that a film of highly resistant oxygen gas is formed next to the aluminum. As this film forms, the current through the cell is cut down until it ceases altogether. At the same time a slight amount of hydrogen is evolved at the lead electrode.

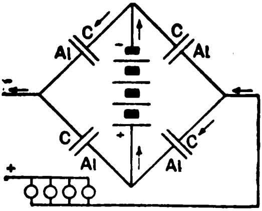


Fig. 1

The evolution of these gases continues only for a length of time required to build up the film and cut down the current to zero.

When the aluminum plate is negative and leakage through the oxide film begins, ionization of the acid takes place as before; hydrogen gas is now evolved at the aluminum electrode, and the oxygen ions, which before went to the aluminum, now are attracted to the lead, where they are evolved as neutral oxygen gas. No oxygen film can form on the lead plate and the current flow is not reduced.

The aluminum plate thus acts as a valve, permitting current to flow when the aluminum plate is negative and preventing it from flowing when the aluminum plate is positive. The formation of the film takes an appreciable time, and the longer it takes the lower is the efficiency of the cell as a rectifier.

The film is liable to disappear rather quickly when the current passes through its zero value, and the leakage of current which takes place when the aluminum is positive is usually high enough to render the rectifier very efficient. The leakage is greatly increased by the presence of impurities in the solution. The presence of an ion of chlorine, bromine or iodine in the electrolyte will completely destroy the valve action. Cells of this type are commonly used by radio amateurs for obtaining high voltage direct current for plate voltages in transmission. A number of cells are placed in series to obtain this result. Carbon is generally used instead of the lead.

Carbonate or borate solutions are preferred to sulphuric acid, as when the cell is not in operation the acid will attack the aluminum, while the others will not. Moreover, the breakdown voltage of the film with an electrolyte of sulphuric acid used with an aluminum electrode is too low for most practical purposes. The rectification is not perfect, for as the voltage across the electrode is increased leakage through the gas film takes place, until at a certain voltage the film breaks down completely, and a large flow of current results. In the case of an aluminum cell using sulphuric acid as the electrolyte this critical voltage is about 25 volts. With ammonium borate it is about 500 volts, with ammonium phosphate it is 360 volts. The following table gives the maximum voltages attained in various baths by aluminum and tantalum (Metals and Metallic Compounds, U. R. Evans).

Aluminum		*Tantalum*	
Ammonium borate	500	Sulphuric acid, very dilute	430
Ammonium phosphate	360	Hydrochloric acid, dilute	210
Ammonium carbonate	260		
Sulphuric acid	25		

The maximum voltage which can be withstood before a breakdown of the film occurs varies very greatly with the nature of the bath; maximum voltage is generally greater in dilute solutions than in concentrated solutions, although exceptions to this rule are known.

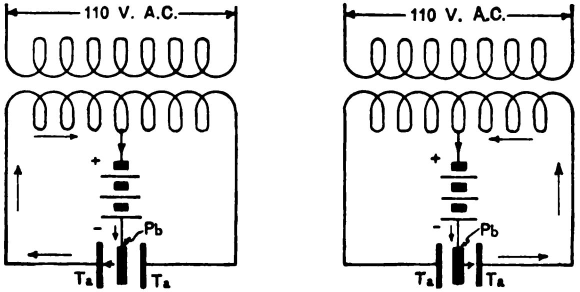


Fig. 2

Figure 1 shows the method of connecting four of these cells so as to rectify both half-waves of an alternating current. The direction of flow is indicated by the arrows, and is shown for both halves of the cycle. The current in each case through the battery which is being charged is in the same direction. The lamp bank indicated is for regulating the current through the cells, and hence regulating the charging rate of the battery.

The aluminum rectifier has not met with much success. The film is likely to disappear rather quickly when the current is turned off, and the leakage of cur-

rent during the "anodic" half-periods is considerable. This leakage is increased by the presence of impurities in the solution. The tantalum rectifier, although its critical voltage is somewhat lower than that of the aluminum type, is able to withstand a sufficiently high voltage (over 100) for all practical radio purposes. It has the additional merit of being able to form a gas film instantly on reversal of current. Tantalum is also inert to acid attack, the electrolyte used in a tantalum rectifier on the market being sulphuric acid. During operation the water in the cell is electrolyzed, so that it is necessary to occasionally add water to replace that which disappears in the form of oxygen at the lead electrode and hydrogen at the aluminum electrode. Unlike the aluminum plate rectifier, which is extremely sensitive to variations in temperature of the electrolyte, the operation of the tantalum rectifier is practically constant over a wide range of temperature, and is independent of changes in frequency and line voltage.

Figure 2 shows the connection for rectifying both half-waves of the cycle, using a cell with two tantalum electrodes and one lead electrode. The voltage to be rectified is stepped down from the line voltage by means of a step-down transformer. Diagrams for both halves of the cycle are shown.

Electrolytic cells can cause no electrical disturbances in the line, since there are no circuits to be opened and closed or to oscillate. They require a minimum amount of attention on the part of the operator, requiring only water occasionally. They are able to handle currents large enough to charge small storage batteries satisfactorily, but attempts must not be made to use them to rectify heavy currents. The result would be excessive gassing, destruction of electrodes, and a high temperature of the electrolyte. These failings are characteristic of the aluminum type, but have been partly overcome in the tantalum type using a special electrolyte of sulphuric acid and some other material.

A counter-emf. of about 3 volts is developed by the tantalum cell. There is a maximum voltage above which the cell will not operate, as mentioned before, due to breakdown of the film, and this voltage must be taken into consideration when determining how many cells to use in series in each arm of the bridge connection illustrated above.

It will charge 3 cells of storage battery at 3 amperes at a power input of 65 watts. When charging 2 cells at 1 ampere, the power input is about 18 watts, and when charging 1 cell at 2 amperes it is about 29 watts. The efficiencies of electrolytic cells are of the same order as those of other types of rectifiers.

In the next issue we will discuss the operating characteristics of electrolytic cells and their applications.

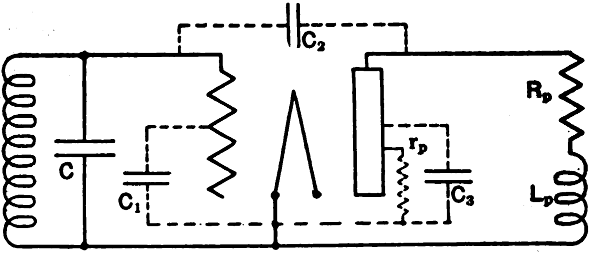
PLATE CIRCUIT CALCULATIONS

After designing the open or antenna circuit and the closed or secondary circuit, the next circuit to be considered is the plate circuit. The design of this circuit is just as important as the design of the other circuits, but as a rule, it is poorly designed, with the result that the distance range of the set suffers materially and the signals when received are considerably distorted. It should be the ambition of the experimenter to obtain best results; not to strive after great distance and fair or poor quality, or good quality and short distance, but to obtain reasonable distance and good quality. Quality should be the first point to be considered, as it is this which makes radio both practical and enjoyable. Distance range should be considered only after quality of reproduction, as when a set has been adjusted to reproduce with good quality, it will always be found that the range of the set has a reasonable value over which consistent and regular communication can be maintained. Many experimenters have the distance fever; how far Tom Jones received on his set on May the fifth at 2 A.M. is of no value to radio science unless he can do the same thing every morning. These thoughts must be kept in mind always; these are the things that make radio practical.

Plate circuits may be either tuned or untuned. The latter design is the more frequent, as it is employed in almost all audio-frequency amplifying circuits. We will deal with this type of circuit in this article, and cover the other types in succeeding issues. Untuned plate circuits may be either regenerative or non-regenerative. The theory of regeneration will be covered in the near future in Radiofax. It will be sufficient to state here that when the plate circuit is inductive, the apparent resistance becomes negative, tending to neutralize the grid circuit resistance. This is the condition for regeneration. When the plate circuit inductance becomes great enough, the circuit resistance may become completely neutralized, in which case oscillations will be set up. Maximum regeneration occurs when the circuit resistance has been exactly neutralized. If the plate circuit inductance be increased beyond the critical value required for maximum regeneration, the grid circuit will deliver power instead of absorbing it, and oscillations will occur. In this article we will consider the value of inductance required in the plate circuit to give the maximum regeneration.

Regeneration may be accomplished either by this effect of inductive plate circuit together with the coupling effects of electrode capacity in the tube, or by mutual inductance between a tickler coil and a coil in the grid circuit. We will treat in this article of the first method only, viz., that of securing the coupling through

the tube capacity. We will show how to calculate the maximum plate-circuit inductance for regeneration (or minimum inductance for oscillations).



Consider Fig. 1. The tuning coil has a high-frequency resistance R, the secondary condenser has a capacity C, the capacity C_1 exists between the grid and filament of the tube, C_2 between the grid and plate, C_3 between the plate and filament. The tube has an amplification factor μ, and internal output impedance r_p. For complete neutralization of the circuit resistance, and hence oscillations, the inductance required in the plate circuit is given by

$$L_p = \frac{Rr_p(C + C_1 + C_2)^2}{\mu C_2} \qquad \mu h,$$

in which R, r_p are in ohms, and the capacities in μf. The inductance L_p is given in μh.

To illustrate the application of this formula, let us suppose that we have decided to use a UV-201-A Radiotron as detector. Referring to the article on this tube in the October Radiofax we find that to operate it as a detector requires a voltage of 40 on the plate and a grid condenser of 0.00025 μf. giving a grid potential of about ¾ of a volt, negative.

Next obtain the various values required in the equation above. To obtain the value of r_p refer to the characteristic curves of the UV-201-A. For 40 volts plate the curves indicate an amplification factor of 6.5. The equivalent plate voltage is then

$$40 - 6.5 \times \tfrac{3}{4} = 35.1 \text{ volts}$$

The amplification factor μ corresponding to this plate voltage is 6.45, and the plate resistance r_p is 21,000 ohms.

Information as to the internal electrode capacities in the tube is rather scarce, but for our purpose it will be satisfactory to take a value 15 $\mu\mu f$ each for C_1, C_2 and C_3. In the design of the secondary circuit in the January issue we have decided upon a value 0.0005 μf for C.

The value of R, the high-frequency resistance of the oscillatory circuit comprising the secondary of the coupler and the secondary condenser, for this case will be taken as approximately 6 ohms. Methods of calculating

high-frequency resistance of conductors and coils will be given in a future issue of Radiofax.

Substituting all these values in the equation above, we have

$$L_p = \frac{6 \times 21{,}000\,(.0005 + .000015 + .000015)^2}{6.45 \times .000015} = 367\,\mu h;$$

that is, for the effective resistance of the grid to be completely neutralized and oscillations to be set up, the inductance in the plate circuit must have the value 367 μh. This is the least value for oscillation and the maximum value for regeneration, when the set is receiving the longest wavelength it was designed to receive. This inductance is furnished by a coil of 75 turns of No. 24 D.S.C. wire, wound on a core 3.25 inchès in diameter. The full capacity of the variable condenser is in use, and the set is tuned to an 800-meter (375 kilocycles) wavelength.

By referring to the formula, it will be seen that since the secondary capacity, C, must be greater for the longer wavelengths than for the shorter ones, the value of L_p, to reach the critical point, will be less for the shorter waves. The inductance coil used, then, must be variable. There are many cases in which it is difficult to prevent the circuits from oscillating. This has been found to be particularly difficult in some of the reflex circuits when tuning near the upper limit of the wave range of the sets. This is evidently due to the presence of too much inductance in the plate circuits. If the resistance of the plate circuits, R, be increased, the formula shows that more inductance would be required to set up oscillations than we have in the circuit. Hence, stability may be secured in these circuits at the lower frequencies (longer wavelengths) by connecting a resistance in series with the plate.

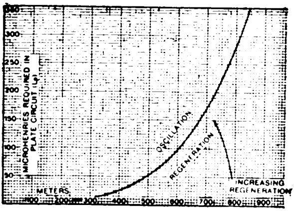
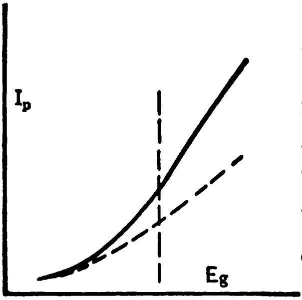


Figure 2 shows the relation between the wavelength of the secondary circuit and the amount of inductance required in the plate circuit to furnish the critical adjustment for maximum regeneration. The value of inductance required has been calculated from the above equation for various values of the tuning capacity C, and then plotted against the wavelength corresponding to these values of capacity in combination with the secondary of the variocoupler. It will be noticed that the inductance required increases with the wavelength.

The tube in this circuit is obviously to be used as a detector. Detector action depends upon the rate of curvature of the characteristic curve. If there is a

high resistance or reactance in series with the "B" battery, the effect is to straighten out the characteristic curve throughout the whole extent of the curve, as shown in Fig. 3, thus materially impairing the detector action of the tube. The reactance of a pair of phones for radio-frequency current may be very high, hence this effect might exist in this circuit; to eliminate it a condenser should be used in shunt with the phones, thus furnishing a low impedance path for the high-frequency current and so maintaining the plate voltage constant as the grid potential fluctuates. (It is this variation of plate potential that causes the dynamic characteristic to have a smaller slope than the static characteristic.) The effect of this capacity on the total inductive effect in the plate circuit is negligible. The inductive effect of a 0.001 μf condenser in shunt with the phones is only about 0.018 μh. which is negligible compared with the inductance 367 μh required in the circuit. The effect of even the phone cords by themselves, without the shunt condenser, is only in the neighborhood of 0.5 μh. In any event, the phones may be neglected in these calculations, and the use of a shunt phone condenser is recommended for best results.



In conclusion, we shall anticipate a question that will, in all probability, arise in the mind of more than one reader of this article—why is the UV-201-A picked out as a detector! It must be understood that although the UV-200 is in general used as a detector, its operation is unstable, great sensitivity being obtained as a result of this instability which is due to the presence of gas ions in the tube. Morever, it is impossible to obtain reliable values of the plate inpedance and amplification factor. (See the article on the UV-200 in this issue.) Accurrate information on the UV-201A is readily available.

STORAGE BATTERIES

There are two types of lead cells—the Planté type and the Faure. These do not differ in theory or practice; the difference is mainly in the method of formation of the active material of the plates. In the Planté type, pure lead plates are oxidized electrically, giving a surface of lead peroxide on the plate. This forms the positive plate. Other plates treated in the same manner are then subjected to a flow of current in the reverse direction, resulting in reduction of the lead oxide to a lead sponge. This forms the negative plate. In the Faure type, the active material on both plates, instead of being formed electrically, is applied in the form of a stiff paste to a stiff lead-antimony alloy supporting grid. These plates are then assembled in a bath of dilute sulphuric acid with dummy lead plates for the opposite electrode and a current passed through the whole. If the plates were pasted with litharge or red lead, the current reduces this to lead peroxide, thus forming the positive plate. Negative plates are formed by passing the current in the opposite direction, reducing the lead oxide to sponge lead.

The Faure type is used chiefly where it is desired to obtain the greatest possible capacity with a minimum of weight and space occupied.

The chemical changes taking place in charging and discharging are complicated in their details, but the change from initial to final products may be represented by the equation

$$\underset{+\text{ plate}}{PbO_2} + 2H_2SO_4 + \underset{-\text{ plate}}{Pb} = \underset{+\text{ plate}}{PbSO_4} + 2H_2O + \underset{-\text{ plate}}{PbSO_4}$$

$$\text{charge} \leftarrow \qquad \rightarrow \text{discharge}$$

The equation read from left to right is the equation of discharge; if read from right to left, it is the equation of charge; that is, on discharge, the acid combines with the lead oxide to form lead sulphate on the positive plate. More of the acid combines with the lead to form lead sulphate on the negative plate. At the same time water is formed, which reduces the specific gravity of the acid solution. When under charge, the negative plate gives up its sulphur and oxygen to the water, forming sulphuric acid again and leaving pure lead sponge on the negative plate. The positive plate also gives up its sulphur and some of its oxygen to the water, forming more sulphuric acid, and leaving lead peroxide again on the positive plate. Nothing is lost in the cycle of charging and discharging. The only thing that has to be added to the battery from time to time is water.

When fully charged, the specific gravity of the electrolyte is between 1.210 and 1.300. This point is fixed by the fact that the resistance of a solution of sulphuric acid is least when its specific gravity lies somewhere between these two values. This corresponds to 2 parts of water by weight to each part of acid of sp. gr. 1.84,

by weight; or, 7 parts of water by volume to each part of acid of sp. gr. 1.84, by volume, at 60° F. In mixing acid and water to form the electrolyte, the water must never be poured into the acid. Excessive heating and sputtering may occur, with danger of sustaining severe acid burns.

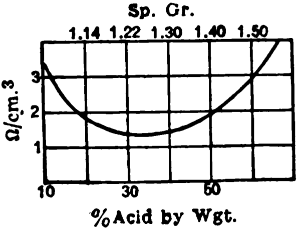


Fig. 1

The capacity of a storage cell depends on various conditions, such as the temperature, the rate of discharge, the strength of the electrolyte, the character of service to which it has previously been subjected and the attention it has received, besides the amount of active material on the plates and the active surface exposed to the electrolyte. The idea of the capacity of a storage cell may be obtained from the following illustration:

The terminal voltage of a certain battery was read for a certain value of discharge current until the voltage began to drop considerably. With the particular battery this occurred at the end of about 6 hours, and the curve obtained from these readings was that shown in Fig. 2, curve (1). A storage battery is considered completely discharged when the voltage begins to drop rapidly. It is noticed that the voltage at this point is about 1.76 volts.

A number of tests of this sort were run and curves drawn, and the initial, average and final values of terminal voltage were plotted, as shown in Fig. 2. If a line be drawn from the 1.76 volt point on the vertical scale to the curve of final voltage, the discharge current for that voltage is 5.67 amperes. These curves then give the discharge rate and capacity of the battery. They are for one cell only. The capacity of the cell is then $6 \times 5.67 = 34$ ampere-hours per cell. (Ampere-hours = amperes $\times$ hours.) The capacity of the cell may also be expressed in watt-hours of energy. For this purpose we require the average voltage of the cell. The curve in figure indicates a terminal voltage of 1.98 for a discharge rate of 5.67 amperes. The capacity is $1.98 \times 5.67 \times 6 = 67.5$ watt-hours. (Watt-hours = watts $\times$ hours = volts $\times$ amperes $\times$ hours.)

If the cell be discharged at higher rates than the rated, the terminal voltages will be lower at all times, and the corresponding capacity will be smaller. Suppose we discharge a cell at a rate of 20 amperes. To find the number of hours over which the battery could discharge this current we might divide 34 by 20 and obtain an hour rating of 1.7 hours, but this would not

be correct. The capacity is lower than this, due to the depletion of the acid in the pores of the plates. At high rates of discharge, the acid in the pores in contact with the plate is withdrawn from solution more rapidly than it can be replenished by diffusion from the free electrolyte in the cell. It is this limitation of available acid that limits the capacity at high continuous rates of

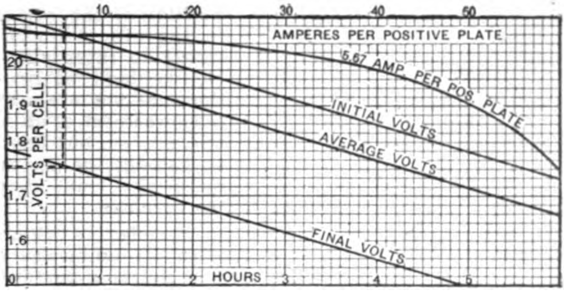


Fig. 2

discharge rather than any limitation due to the plates themselves. This explains why in a battery, after being exhausted at a high discharge rate, the balance of its normal capacity can be obtained by continuing the discharge at lower rates, or by allowing the battery to recuperate while standing on open circuit for a time. It is also for this reason impossible to damage the plates by over-discharge at high rates, as the voltage of the battery will drop below a usable value before the active material in the plates is discharged to the danger point. This is a point worth remembering, as it is contrary to the prevalent belief.

Figure 3 shows the capacity curve of this particular cell. It is to be noted that at a discharge rate of 20 amperes, the hour rating is only about 1.07 hours. This would make the capacity $1.07 \times 20 = 21.4$ ampere-hours. This is made clear by the broken lines in Fig. 3, and, compared with the 6-hour rate, shows how rapidly the capacity drops off with increasing discharge current.

When the discharge is intermittent, the reduction in available capacity due to high rates of discharge largely disappears on account of the time between discharges to allow diffusion of the acid into the pores of the plates.

The charging characteristics of a battery are determined by the same things that determine the discharge rate, mentioned above. To fully charge a battery after discharge, it is necessary to pass through the cells in the proper direction (opposite to that of discharge) an amount of current equal in ampere-hours to that taken out on discharge, plus some excess to make up for losses.

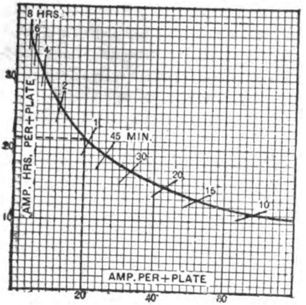


Fig. 8

If the charging rate is not too high, all the current is useful in charging the battery. If the rate is increased, a point is reached where gassing occurs, due to decomposition of the water in the electrolyte. Charging rates sufficiently high to produce gassing are not only wasteful of electric energy, but tend to dislodge the active material from the plates and produce excessive temperature rise.

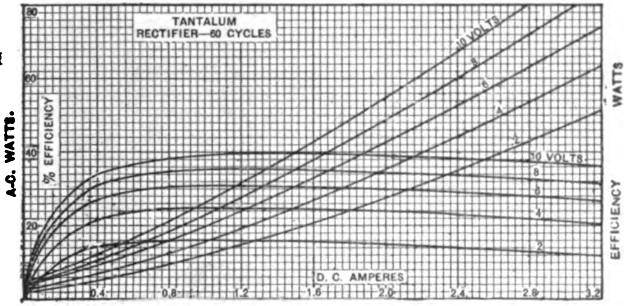
In general, any charging rate is permissible which does not produce excessive gassing or a cell temperature exceeding 110° F. The value of the charging current at which gassing begins depends upon the factors mentioned above, but the principal factor is the state of charge of the battery. When a battery is fully charged, any rate, however small, will produce gassing, but this rate may be reduced so that the small amount of gassing that results is practically harmless. This safe rate is called the "finishing rate." The more completely the battery has been discharged, the greater may be the initial rate. The method of diminishing the rate toward the finish of the charge is called "tapering" the charge. A battery may be charged at any time when a charge will be useful; it is not necessary to wait until it has been completely discharged. A general rule for determining the maximum permissible rate of charging is: The charging rate in amperes must never exceed the ampere-hours out of the battery. Any method of charging that keeps the charging current within this limit will not overheat the battery or cause it to gas. If the cell mentioned above has been completely discharged, the charge may be started at 34 amperes. In a quarter of an hour the rate must be decreased ¼ × 34 or 8.5 amperes, giving a rate of 25.5 amperes, and so on. The intervals may be chosen to suit the convenience of the operator.

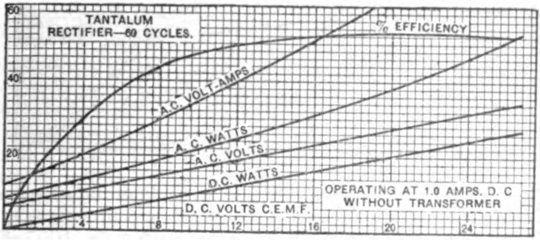
The characteristics shown by this method will be approximated if the constant voltage method is followed, provided the proper voltage can be chosen. A value of 2.3 volts per cell is usually considered as a good average value, although some adjustment may be necessary between summer and winter. This method requires a minimum amount of attention of the operator and lessens trouble that may follow from any excessive overcharge.

ELECTROLYTIC RECTIFIERS

Very little data is available covering the range of electrodes having rectifying properties, but aluminum and tantalum have been in commercial service for some time. It has been found that electrolytic rectifiers are considered practical for rectifying small currents, but can be constructed to handle relatively large currents if provision is made for artificial cooling. Rectifiers for currents in excess of 2 or 3 amperes are difficult to maintain and construct, unless they are employed in intermittent service only.

In general the tantalum rectifier is more suitable for operation at low battery voltage, that is, voltages not exceeding 20 to 25 volts, and at fairly high current

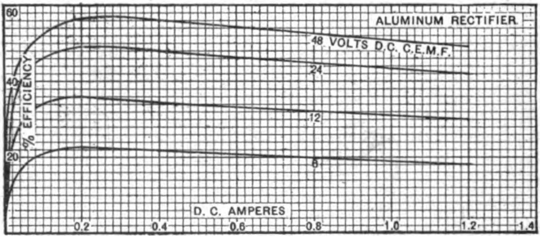


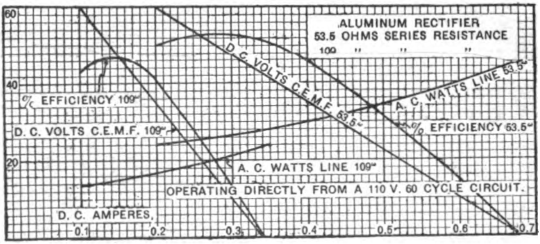


rates, that is, up to 2 or 3 amperes; whereas the aluminum rectifier is suitable for operation at higher voltages, but is more limited with regard to the value of the current rectified. Under suitable operating conditions, the tantalum rectifier has the advantage of more permanent characteristics and much lower maintenance, and also has the advantage of temperature stability; that is, its performance is practically unaffected by the temperature of the electrolyte over a wide range. With aluminum rectifiers, high temperatures are destructive to the performance as well as to the electrodes.

One form of tantalum rectifier has electrodes of tantalum and lead, the electrolyte being dilute sulphuric acid. The density of the electrolyte is not of great importance, and the performance characteristics are almost independent of temperature over the range tested from 40° F. to 160° F. The plate area and spacing of the electrodes do not appear to be of great importance. The power-factor of these outfits is about 55 to 65%.

In the case of either the aluminum or tantalum rectifier, the efficiency improves with decreasing frequency, but within the range 25 to 60 cycles, the variation is unimportant. The tantalum rectifier is practically independent of temperature over a wide





range; the aluminum rectifier, however, is much affected by high temperature and with some electrolytes the reduction ceases at temperatures as low as 105° F.

The break-down voltage of the tantalum rectifier begins at about 85 volts maximum, which limits the battery voltage to about 30 volts. Better performance is obtained if the battery voltage does not exceed 20 to 25 volts d-c., requiring an a-c. effective voltage of not over 30 to 35 volts. The break-down voltage of the aluminum rectifier begins at about 185 volts maximum, which limits the battery voltage to about 75 to 80 volts, with a corresponding a-c. voltage of about 80 to 85 volts. When the aluminum rectifier is operated directly from a 110-volt bus, the battery voltage for best results should not exceed 40 to 45 volts.

ACTION OF GRID CONDENSER

The three-electrode vacuum tube may be used as a detector of high-frequency oscillations by taking advantage of—

(a) The curvature of the plate current-grid voltage curve,

(b) The establishment of grid currents,

(c) Combinations of these two,

(d) Rectification by grid condenser.

The first case is the most familiar; as the plate voltage is increased while the grid voltage is held constant, the characteristic curve becomes steeper and steeper. Consequently, an increase in plate voltage produces an increase in plate current which is greater than the decrease in current produced by an equal decrease in voltage. This effect is more pronounced at the curve. It is equally pronounced at the upper sharp bend, but here the decrease is greater than the increase.

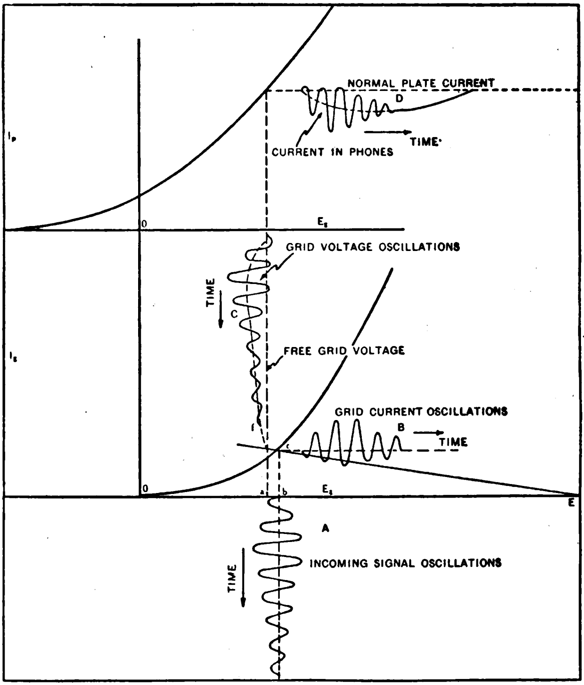
The grid potential is always sufficiently negative to prevent the flow of grid current.

The second case was treated in the September issue of Radiofax in the article entitled "Grid Currents," p. 29. Here it was shown that, due to the flow of grid current when the grid is positive, the negative potential attained by the grid during the negative half of the cycle is greater than the positive potential attained by it during the positive half of the cycle. If the plate characteristic were straight, then, the increase of plate current during the positive half of the cycle would be less than the decrease during the negative half. From case (a) above, it will be seen that when we are working at the upper bend of the plate characteristic, the curvature of the characteristic adds to the rectifying effect, while when we are working at the lower bend, the curvature lessens the effect.

The third case is the subject of this article, and can best be explained in connection with the accompanying figure. The rectifying action of the tube with grid condenser requires a positive bias. This may be news to many of our readers; generalizations will be made below as to the proper grid bias to use in the various cases. In the figure, A represents the incoming signal oscillations. The grid is maintained at such a positive potential with respect to the filament as to work at the bend of the grid current-grid voltage curve, as shown. Rectifier action takes place on this grid current, with the result that the increases are generally greater than the decreases, as shown at B.

Since the grid is, on the average, more positive than negative, it absorbs some of the electrons flowing from the filament to the plate, thus decreasing somewhat the flow of plate current. This effect is small, although it adds to the total effect. and is not indicated in the dia-

gram. This accumulation of electrons lowers the positive potential of the grid somewhat, as represented by the broken line at C. The figure shows one wave-train. The negative charge on the grid must be allowed to leak off in time for the next wave-train. In soft tubes the charge may be neutralized by combination with the positive gas ions. In hard tubes the leakage must take place either through imperfect condenser dielectric or through a special leak resistance inserted for the purpose.



All the grid current which flows must pass through this leak resistance. There is, consequently, a resistance drop in voltage which determines the original bias on the grid. In the diagram, the point marked E represents the voltage drop in the filament; if from this point we measure back a distance equal to the resistance drop in the leak to b, and vertically a distance equal to the grid current to c, the line Ec may be drawn, the intersection of which with the grid characteristic determines the value of the grid bias. The grid voltage is thus represented by Ob. But even when there is no potential at all on the grid it collects some electrons,

so that its potential is lowered to the point a, which is the "free grid potential." The continuation of the dotted curve at C from the point f back to the free grid voltage represents the leakage of charge from the grid condenser. Without the leak resistance, which offers an outlet for the excess charge that collects on the grid, the negative potential of the grid may become sufficiently high as to cause a material decrease in the plate current which persists during the interval between wave-trains.

The projection of the oscillation C up to the plate characteristic curve gives the output or plate current D. It is thus seen that there is considerable decrease in the phone current. We have, then, rectification, due to the cumulative action of the grid condenser, obtained by working at the bend of the grid characteristic, and amplification at the same time, due to working on the straight portion of the plate characteristic.

As a result of these studies we can now arrive at a generalization as to the proper grid return connections to use to furnish the proper grid bias. Thus for all hard tubes used as detector or amplifier, without grid condenser, connect the grid return to the negative side of the "A" battery; for all hard tubes used as detector with grid condenser, connect the grid return to the positive side of the "A" battery; for soft tubes with grid condenser, connect the grid return to the negative side of the "A" battery. The reasons for these statements may be found in the following: For distortionless amplification no grid current must exist, hence the negative bias; for rectification by case (a) above, no grid current may exist, hence likewise the negative bias; for rectification with grid condenser, grid currents are required, hence the positive bias.

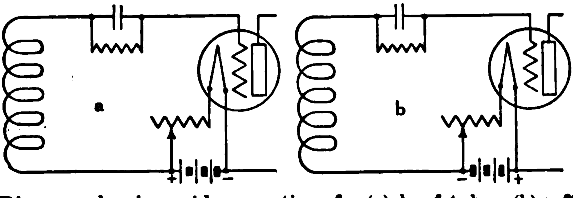
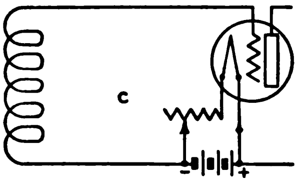


Diagram showing grid connections for (a) hard tubes, (b) soft tubes, with grid condenser.

In the case of the soft tube used with grid condenser, the presence of gas in the tube causes the input impedance to be considerably lower than that of the harder tubes. There is, therefore, the tendency for grid current to flow at much lower positive voltage. Although a grid current is required for rectification with grid condenser, too much grid current is detrimental in causing a decrease in the plate current. This is because

the grid, when positive, robs the plate of some of the electrons coming from the filament which ought to go to it. For this reason, best results are obtained by placing a negative bias on the grid, that is, by connecting the grid return to the negative side of the "A" battery.



(c) Diagram showing grid connection for amplifier.

These connections are illustrated in the accompanying diagrams are in agreement with the recommendations of manufacturers of vacuum tubes. The General Electric Co. recommends connection of the grid return to the positive side of the "A" battery for all their receiving tubes, excepting the UV-200, when used with grid condenser. When used as amplifiers, or without grid condenser, the grid return is to go to the negative side. The UV-200 used with or without grid condenser is to have the grid return connected to negative terminal.

The proper value of grid condenser and grid leak resistance to use depends upon many variable factors, so that it is impossible to calculate them. This has led to the use of apparatus designed to provide variable values. There are several facts, however, which may act as guides to use in determining the best values experimentally. If the condenser is too large it will not be charged to as high a potential during a wave-train, and, consequently, it will take a longer time for the charge to leak off. If it is too small the charge will leak off too rapidly, and the grid voltage will not be depressed sufficiently for good operation as a detector. The same remarks may be made with regard to the resistance of the leak. In general, the product of the leak resistance and the capacity of the condenser must be small compared to the time between the successive wave-trains of a signal.

On the other hand, the capacity must be as large as possible, and the resistance must be high, otherwise a large fraction of the signal voltage will be used in the condenser and be of no service in producing sound in the phones. Values recommended by the manufacturers are as follows: For the UV-200, 201, 201-A, 199, WD-11 and 12, 0.00025 μf. For tubes having large internal capacity, larger values of capacity and lower resistances are better suited. Grid leak resistances range from about ¼ to 10 megohms.

REPORT ON THE TEST ON RECTIFIERS FOR BATTERY CHARGING

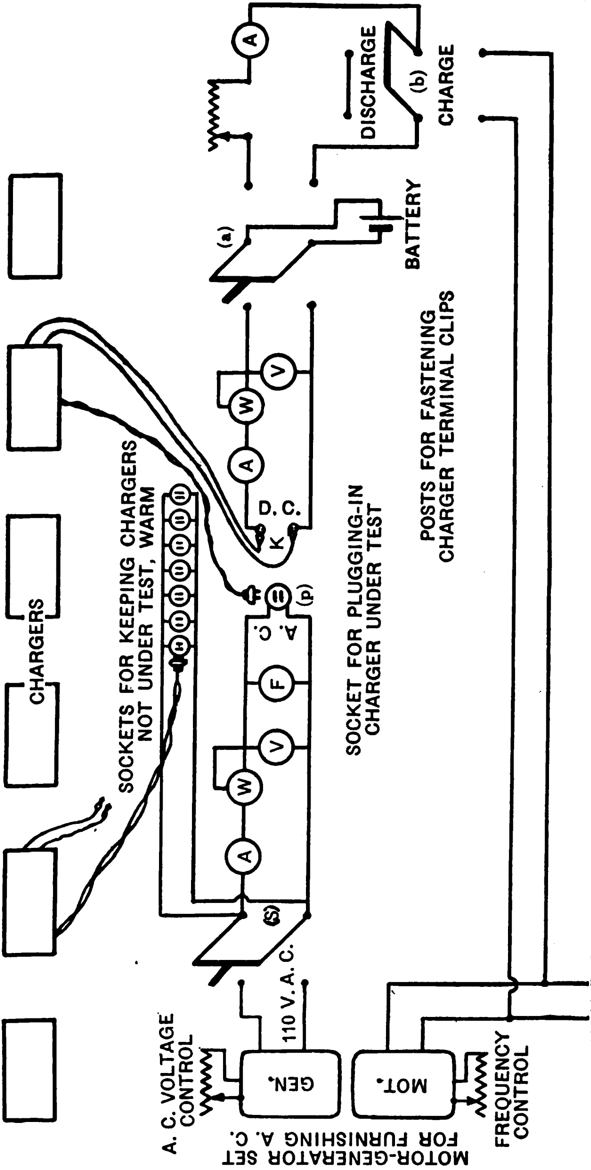
In the September issue of Radiofax a series of articles discussing the various types of rectifiers for battery charging was begun, the initial article dealing with the bulb type of rectifier. At the end of this article a table was presented which gave the efficiencies of various sizes manufactured, the values for which w re taken from a pamphlet published by one of the manufacturers. Very soon after the issue was out we received letters from several of the manufacturers of vibrating rectifiers who objected to the values given in this table as being too high, and at the same time giving us the efficiencies of their own apparatus. We noticed that these varied considerably, having a total range of from 30 to 80 per cent. It seemed highly improbable to us that there could possibly be such a great variation in the efficiency of apparatus of the same type used under the same conditions and for the same purposes, and, therefore, we wrote to all manufacturers whose na es and addresses we could obtain to send us their apparatus for test. From the published material available at the time it was impossible to obtain information which could act as a guide to the prospective purchaser of rectifying apparatus. Moreover, in their effort to impress the prospective purchaser with the good qualities of their apparatus some of the manufacturers made statements which were, if not untruthful, at least misleading.

In this article we present the report of the tests run on those rectifiers which were submitted to us. We have made every effort to be fair, if not generous, to the manufacturers—brand new apparatus only was run in the test, all the charge s coming from the factory where the manufacturers were able to adjust for optimum conditions or highest efficiencies or whatever they wanted to feature.

The Test

Four types of chargers were submitted, viz., bulb, vibrating or mechanical, electrolytic and motor-generator. The general theories of operation of these various types have been explained in the issues of Radiofax from September to January inclusive. These articles, together with this report, will constitute the most complete and comprehensive treatise on rectifiers for radio battery charging available at the present time. A photograph of those tested is shown on page 11. This cut also includes one which was not tested, as when it was received it was found to have been injured in transit, and rather than have anything but perfect apparatus in the test we made no attempt to repair the damage.

A considerable amount of apparatus was required to make this test, as the photograph which will appear in



Wiring Diagram of Test

the following issue will attest, the total value of the apparatus being in the neighborhood of several thousand dollars. The accompanying wiring diagram does not show this, as it must be remembered that it was necessary to use meters of various ranges for chargers of various ratings. All measuring apparatus used was calibrated for accuracy before the test, so that these results may be held to be correct, with a precision far in excess of that required when we consider the usual condition of operation of the chargers.

In this issue we will discuss the procedure followed, and explain the various points to be considered and the extreme amount of care required to be sure that no departure from actual operating conditions resulted.

Procedure

Following the diagram, the alternating current to be rectified was obtained from a motor-generator set to run on 110 volts d-c. as shown at the left of the diagram. As all the rectifiers were rated at 110 volts, 60 cycles, it was necessary to be sure that these were the conditions prevailing at the time any readings of the meters were taken. Hence it was necessary to furnish voltage and frequency controls as indicated in the diagram, the frequency being controlled by the speed of the motor-generator, and the voltage by the strength of the generator field. This 110 volt, 60 cycle current was then passed through a double-pole single-throw switch shown at s in the diagram, whence it passed through an ammeter and wattmeter to the plug-in socket at p. The voltage and frequency could be read on the meters indicated.

Conditions Maintained

Since it was necessary to keep to the usual operating conditions, it was necessary to make provision for keeping the chargers warm. Considerable variation in results would be obtained if some of the readings were taken with the chargers warm some times and cold at other times. Hence a bank of plug-in sockets was provided connected to the switch in such manner that their operation would have no effect on the readings of the meters. All these plug-in sockets served as points of entrance for the alternating current into the chargers through the lamp-cords provided by the manufacturers. Thus, while a particular charger was under test it was connected at p as shown, the other chargers being connected to the bank of plug-in sockets to keep warm. As soon as a set of readings was taken this charger was plugged back into the bank, and the next one inserted at p.

The direct current furnished by the chargers was taken off through leads furnished with battery clips at their ends. These clips of any particular charger under test were attached to posts provided at k, the output leads of the chargers not under test, but being kept warm, were left free, unattached to anything.

The pulsating direct current furnished by the charger at k is then led through the direct current ammeter and wattmeter, as indicated, the voltage also being indicated by the meter. The battery to be charged is shown connected to the double-pole double-throw switch a, which when readings are taken is thrown to the left.

Various States of Charge

It is obvious that if we wish to take measurements for various states of charge of battery, that a method of charging the battery at a faster rate than could be provided by the chargers themselves must be provided, otherwise the test might run into weeks and perhaps months. Therefore, as will be noticed, if switch a be thrown to the right and switch b be thrown down, the battery will be connected to the 110 volt d.c. line through the rheostat shown at the right-hand end of the diagram. The charging current as indicated by the ammeter can be adjusted by this rheostat. The advantage of this arrangement can be seen when we remember that the highest charging current furnished by any of the chargers is about 9 amperes, while the 80 ampere-hour battery used can easily stand a charging rate of 60 or 70 amperes when fully discharged As the battery charges up, of course, the charging rate must be reduced, so that excessive gassing does not occur as explained in the article in the January issue on storage batteries.

It was not possible to connect in all the chargers at the same time, due to the lack of space and the possibility of confusion due to the maze of wiring, so that some were tested while the battery was being charged and the remainder while it was being discharged. As what we require are the measurements at the various states of charge of the battery, it does not matter how we obtain these various states of charge; hence, instead of totally discharging the battery and going over the process again, it was partially discharged through the rheostat at the right by throwing the switch a to the right and switch b up. When the battery was sufficiently discharged, switch a was then thrown to the left, and another set of readings taken.

Temperature, Voltage, Frequency

We will now consider some of the important quantities which must be kept constant during the test. We have indicated how the chargers must be continually kept warm to simulate actual operating conditions. When a radio fan turns on his charger it is generally at the temperature of the surrounding air. As it operates its temperature rises gradually to a maximum, when the generation of heat in the transformer and elsewhere in the charger is equalled by the rate at which it loses heat by radiation. The charger is cool, then, for only a

short time. The effect of temperature on the operation of the charger will be shown later.

It is very necessary to keep the voltage and frequency the same as those specified in the manufacturer's rating of the charger. The transformer has been designed for operation at 110 volts, 60 cycles, and any deviation from these standard conditions will result in considerably different results in the operation of the charger. Thus, at 62 cycles the carbon contact of one of the chargers became red hot, and at 58 cycles, although the vibrator continued to operate, the battery began to discharge current through the rectifier instead of receiving current from it. The vibrator of this charger is critically tuned so that a slight variation in frequency of the line current produces considerable change in the charging current. It is very seldom, however, that trouble will ensue from variations in the line frequency with any of the chargers, as the maximum variation in commercial lines is seldom greater than one-half a cycle either side of the rated frequency.

The operation of the chargers is likewise dependent upon the line voltage, the delivered current and the efficiency of the charger varying considerably with the voltage. No harmful effects can come, in general, from variation- in commerical lines, but since ratings are given assuming standard conditions, it was necessary to keep to these standards. Moreover, any deviation from these conditions would give anything but smooth curves in the test.

Lag of Battery

One of the most important points to consider in this test is something that relates to the battery rather than to the rectifier. We refer to the lag in the specific gravity of the battery with regard to the actual ampere-hours of charge put into it. That is to say, suppose we charge the battery for a while and allow it to stand. At first the hydrometer will indicate a certain density of electrolyte. After a while it will be noticed that the density changes, gradually increasing until it assumes a value which then remains constant The length of time required until equilibrium depends upon the rate of charge that is used, the higher the rate of charge the longer the time required. Thus it was, in every case, necessary to wait until equilibrium was obtained before taking readings of the meters. In one case, where a rather high charging current was used, it was necessary to wait overnight before equilibrium was restored.

Vibrator Adjustment

Probably the most important point to be considered in the test was the adjustment of the vibrators on the vibrating type of rectifiers. Some of these were extremely critical, the slightest motion of the adjusting

screw starting or stopping the vibrator. In other chargers it was possible to vary the adjustment over wide ranges, thus varying the direct current output of the charger. This type is a rather convenient one to use, as the operator is enabled to adjust the charging current to almost whatever value he wishes within the range of the instrument. This method of adjustment of the charging current, however, is not to be used by the operator. As explained in the October Radiofax, p. 25, sparkless commutation occurs when the circuit is closed at the instant the transformer secondary voltage equals that of the battery. The contacts should remain closed as long as this voltage is higher than that of the battery, and should remain open as long as it is below that of the battery or in the opposite direction. These points are taken care of in the design of the apparatus. The operator should adjust the contacts for the maximum current delivered when the commutation is sparkless, and any adjustment of the current output should be made by adding resistance in series. But even this is hard'y ever necessary, as this is also taken care of in designing the transformer to deliver the proper secondary voltage.

Ease of Adjustment

Ease of adjustment is an important requirement in a charger. The adjustment of most of them was very easy, and in the test the adjustment used was that which gave the rated current to a completely discharged battery when the charger was operated on rated voltage and frequency, that is, 110 volts, 60 cycles. Most of the vibrators operated satisfactorily under these standard conditions, without excessive sparking at the contacts. This sparking at the contacts increased generally as standard conditions were departed from.

The operation of any rectifier for battery charging depends upon the combined operation of the transformer incorporated with the bulb or vibrator or valve-metal (as in the electrolytic rectifier) so that, if it is possible, due consideration should be given the transformer. It is obvious that the ordinary amateur has not the facilities for making exhaustive tests, nor are they necessary, as will be brought out later. But he can at least listen to the charger as it operates and find out whether the laminations are loose or not. The transformer of one of the chargers in the test that had no vibrating element made more noise than all the vibrators put together.

Consideration of the characteristic curves, including delivered direct current, power-factor, efficiency and watts output will be undertaken in the next issue of Radiofax.

AMPLIFIER TRANSFORMERS

Many things have been said, in the various publications, concerning the operation of amplifier transformers as used in radio receiving circuits, but the matter seems to be hazy to the average experimenter. This is due to the fact that very little has been said concerning the *reasons* why these transformers act as they do. From the properties of the circuits in which they are used, and the properties of the transformers themselves, it is possible to predict what their actions will be in the circuits.

The first point to consider is why transformers are used at all. The thing to be accomplished in amplifying is to pass the output of one tube into a succeeding tube, and take advantage of the amplifying characteristics of the tubes. It is the tubes that do the amplifying, and not the transformers. The most a transformer can do is to change the voltage of the circuit. When it does this the current changes correspondingly, but the power passing through the transformer is neither more nor less, neglecting the slight losses that occur.

To transfer the power output of one tube to the input of another we must resort to coupling of one sort or another as the plate current of the first tube could not flow in the grid-filament circuit of the second tube. This may be inductive, or resistive. We will deal here only with inductive coupling.

The relation between the voltage across the terminals of any inductance, the current through it, the frequency and the value of the inductance is given by

$$I = E \div 0.00628\, fL,$$

in which I is in amperes, E in volts, f in kilocycles per second, and L in microhenries. This equation shows that as the frequency increases, the current decreases in the same proportion, for a given value of the inductance and voltage. This point must be remembered in connection with the action of transformers under high frequencies.

When a current is passed through a coil a magnetic field is set up in the coil, the value of which depends upon the values of the current, number of turns of wire, and length of the coil. There is also another factor which enters, viz., the permeability of the core of the coil. The case is simple if the core is air; if it is iron, or any magnetic substance, the effect of the magnetic field is increased many times over the effect produced when the core is of air. This great increase in the field strength due to the presence of the iron increases the value of the inductance in the same proportion, so that, for a given frequency and voltage across the coil, the current through it will be considerably less when the coil has an iron core than when it has an air core. This is called the "choking effect" of the coil.

The reason for the use of air-core transformers in passing radio-frequency currents is then apparent. The frequency is so high that the reactance, which is the denominator in the equation above, becomes very great when the core is of iron, so that very little current is allowed to pass through the coils of the transformer.

The next question that comes to mind is, Why do we use iron-core transformers for audio-frequency transformation? The answer to this is found in considering the nature of the current output of the detector tube.

Referring to Fig. 1, the incoming oscillations impressed on the grid cause variations in the plate current, as at A, in such a manner that the increases in current are greater than the decreases. The greater part of the curves representing these oscillations thus lie to one side of the line representing the mean value of the plate current when no signals are being received. The net effect of a train of oscillations is that of a small increase in the plate current.

The frequency of the output of the tube is so high that the individual oscillations are choked out or smoothed over as they pass through the iron-core transformer. The transformer, however, passes the modulation frequency, which is always sufficiently low as not to be choked out by the inductance of the transformer. Thus we see that the modulation frequency is passed by the transformers. which is all that is desired; whereas, in radio-frequency amplification it is necessary that the radio frequency itself get through.

Since the modulation frequency is so low, furthermore, the inductance of the transformer must be very high to give the value of impedance or reactance required for best operation of the tube. This occurs when the external output impedance is equal to the internal impedance of the tube Air-core transformers could be used, but to obtain the high impedance a great deal more wire would be required, and the apparatus would become too bulky. It would also become more difficult to obtain close coupling between the windings, resulting in magnetic leakage and other losses.

An idea of the frequencies existing in the ordinary electron tube circuits and the action of the two kinds of transformers can be obtained from Figures 1 and 2. Figure 1 illustrates the case of audio-frequency amplification and Figure 2 that of radio-frequency amplification. A comparison of the two cases will best bring out the theory.

The oscillations are shown along the conductors in which they exist. The radio-frequency input is impressed in each case on the grid of the first tube. The characteristic curves drawn next to the grid connections are supposed to have their plate current scales horizontal and the grid voltage scales vertical. The oscillation along the wire to the grids may thus be

projected directly onto the wire connected to the plate. In both cases oscillations on the plate are at the same frequency as the incoming high frequency oscillations. In the A. F. case, a point on the lower bend of the characteristic curve is used for purposes of detection, giving oscillations that have been shifted, due to the fact that their increases are greater than their decreases. At the same time they are amplified a little, but not as much as in the case of Figure 2.

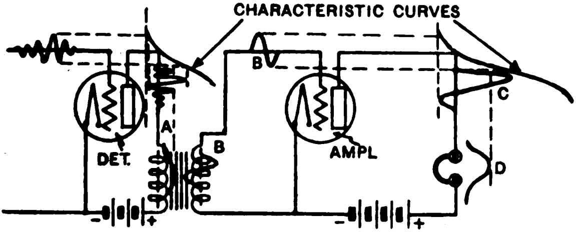


Fig. 1—A. F. Amplification

In the R. F. case (Fig. 2) we are using a point on the characteristic curve near the middle of its straight portion, so that the increases in plate current are equal to the decreases. Also, because the slope of the curve is greater here than at the bend, the amplification is considerably greater.

The output frequency of the first tube in both cases is above audibility. If the shifted oscillations in Fig. 1 could be made to act into any receiver of energy, their net effect would be in a direction determined by the direction in which the oscillations are shifted. This is what happens in the A. F. transformer shown at A, Fig. 1. The high reactance of this iron-core transformer chokes out the high frequency oscillations, so that the effect in the primary of the transformer is that of a single impulse of current for each group of oscillations, always in the same direction. These unidirectional impulses are transformed into alternating currents in the secondary, as shown at B. It must be noted that these oscillations are at a very much lower frequency than the original ones.

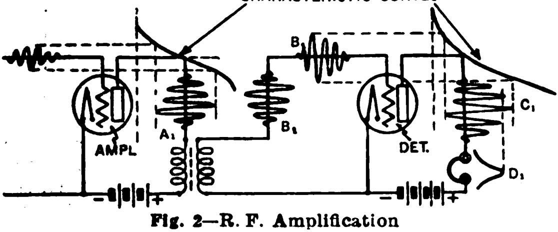


Fig. 2—R. F. Amplification

The radio-frequency currents A_1 in the primary of the transformer (Fig. 2) are not choked out, due to the fact that the reactance of the transformer is low. The oscillations are thus transformed at the same frequency, as shown at B_1.

The oscillating currents then pass on to the grids of the second pair of tubes. In Figure 1 they are amplified and in Figure 2 they are detected. The oscillating outputs of the tubes in the second case are then smoothed over by the choking effect of the telephone receivers, the reactance of which is considerable.

As indicated in the article on the inductance of coils, in this issue, transformers possess internal capacity between their windings and between adjacent turns. This introduces dielectric losses, but on the other hand is effective in tuning the windings to certain frequencies.

The resonance curves of transformers indicate that their impedance is very much greater at all frequencies other than the resonance frequency. At resonance frequency maximum current is allowed to pass through it, so that the performance of any transformer is always best at some particular frequency or range of frequencies. Fig. 3 shows two types of resonance curves. The transformer from which the first has been obtained has been designed to operate over a very narrow range of frequency, the second over a much broader range. High transformer resistance broadens the range, i.e., makes the curve flatter; putting a condenser in parallel does not change the shape of the curve, but shifts it to the right or left, thus shifting the range; the range can be broadened by increasing the amount of iron in the magnetic path, but this decreases the amplification over the range. These remarks apply equally well to air or iron-core transformers.

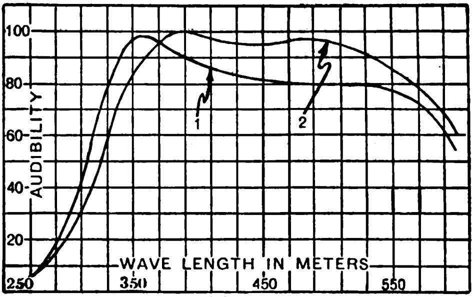


Fig. 3

The turn ratios of amplifier transformers are such that their secondaries may deliver the highest voltage to the grid of the next tube without overloading it, that is, without going beyond the straight line portion of the characteristic curve.

REPORT ON THE TEST ON RECTIFIERS FOR BATTERY CHARGING

(Continued from February Radiofax)

In the February Radiofax we have outlined the procedure of the test and several of the main points to be considered with regard to the use, selection and testing of rectifiers. In this issue we will cover the remaining points and also present and discuss the results of the test. A photograph of the chargers under test is shown on page 7.

Ammeters

Of all the vibrating chargers submitted to us, none were found to have meters that read correctly. The only value attached to the meters is that they tell whether the battery is charging or discharging and no more. In fact, two of these meters gave full scale deflections for any value of charging current, and some were graduated to two or three times the maximum value of current that could be taken from the charger. This is not a good practice for the manufacturers to follow, as it might lead to misconceptions on the part of the prospective buyer or the user.

Some of the manufacturers plead guilty to the use of inaccurate meters on their chargers, and state as the reason that it is impossible to obtain ammeters even approximately accurate within the price that they can afford to pay. Moreover, there are many complications present in chargers which tend to destroy the calibration of ammeters when mounted on them. Even though accurate meters be used there is a possibility that they would read differently on various chargers, even of the same make, which would make individual calibration necessary and increase the cost of the charger.

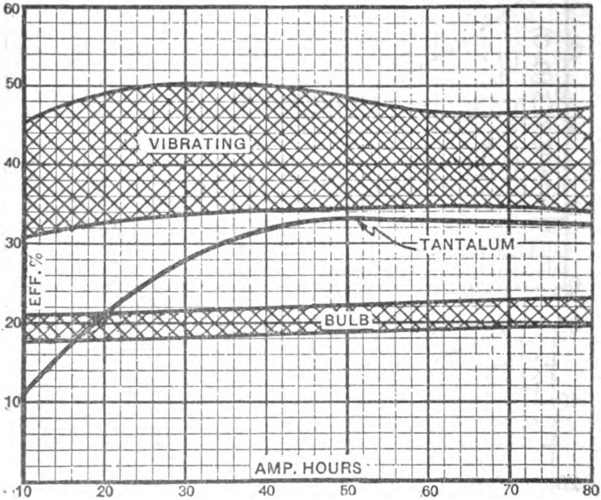
Power Factor

The power factors of all the charg rs excepting one ranged from 50 to 63 per cent. The power factor of the one excepted was very low, due to its poorly designed or assembled transformer. The looseness of the laminations in this transformer was so great that its hum was louder than the noise of all the vibrators. Those chargers which showed the better operating characteristics generally had the higher power factor. It merely happened that this was the case. There is no rule for it, but it generally follows that apparatus that has been properly designed in most respects will also have the higher power factor.

Direct Current Output

The current characteristics of the various chargers are very interesting. In general, the chargers are divided into two classes as regards charging rate, viz.,

All vibrating rectifiers showed efficiencies which fell in the cross-hatched area marked accordingly, and so with the other types. We wish to carefully stress the point here that efficiency is not the all-important thing to consider, the more important things being constancy and ease of operation and freedom from operating difficulties. Thus, the bulb types are perhaps more desirable as regards freedom from adjustments, while the mechanical type is more desirable as regards replacement of parts, and so on. These points will be considered in detail in the next issue of Radiofax. The cost of charging a small battery, such as is used for radio purposes, is generally so small that efficiency loses most of the importance which it assumes in connection with other electrical apparatus. The cost of



charging an 80-ampere-hour battery, which is totally discharged, by means of a charger whose efficiency is 30%, with power at 10 cents per kilowatt-hour is only about 16 cents. With an efficiency of 40% the cost would be 12 cents, and with an efficiency of 20%, 24 cents. When we consider the value of the battery the actual cost of charging becomes insignificant. Besides this, the cost of charging at home is generally much less than the cost of having the battery charged at a charging station, without considering the inconvenience and labor of moving the battery. With a charger handy, the battery is more likely to be kept up to charge and hence be kept in better condition.

The report on the test will be terminated in the next issue of Radiofax.

RADIO CONDENSERS

Sorting the good from the bad

There are three things that are always present in all radio circuits. These are inductance, capacity and resistance. Every electrical circuit contains all three, and no circuit can be built without all three of them. Moreover, no electrical circuit could be operated without all three. The main idea in all circuits is to have these things concentrated at certain points, so that their effects can be more easily predetermined and so that the circuits can be handled and controlled more easily. The presence of each one of these things affects the other, so that in most cases a very complicated action takes place. In designing radio circuits the attempt is made to confine all the inductance to the coils only, the capacities to condensers only, and to eliminate or reduce the resistance as completely as possible. The presence of resistance in a circuit represents a loss of energy or power. In radio circuits, the inductance and capacity are used for tuning the circuit or circuits to resonance with one another. The effect of capacity on the currents and voltages is opposite to that of inductance, so that if these two are used in the circuits in the proper proportions, the effects of each may be neutralized and the circuits tuned to resonance.

This article is the first of a series on the subject of radio condensers that is to run in Radiofax for the next several issues. If our readers will carefully read all these articles they will acquire a knowledge of radio condensers that will be quite comprehensive and complete. The series will be terminated by a report of a test on condensers for receiving, which we are conducting. The ordinary public is acquainted with condensers only by the number of plates in them, as 23 plates, 43 plates, etc.; this does not mean a thing from the electrical point of view. Nobody seems to care about the size of these plates, what they are made of, how they are put together, and so on. All of these things are extremely important, especially the size of the plates and their number. If the fan knows the number of plates. he knows nothing. He must know exactly what the capacity is, and this changes with the size of the plates and many other things.

The Condenser Test

We have written to over a hundred different manufacturers of condensers, asking them to co-operate with us and send in their apparatus for the test. They are coming in thick and fast, every day, and the test promises to be what is urgently required in the radio field—a comprehensive and thorough study of the apparatus on the market, for the purpose of educating the public as to what it is they are buying, the charac-

teristics desirable in the apparatus, and how to use it properly. We have already done this in the field of rectifiers for battery charging; now we are studying condensers, and soon, if all goes well, we will do the same with transformers, and so on. Whatever our readers want, they shall have, regardless of labor or expense.

What is a Condenser?

We have stated above that capacity always exists in every radio circuit and that it is not all confined at one point in the circuit. A condenser is the result of an effort to construct a piece of apparatus that possesses capacity only, without inductance or resistance. We have also stated above that it is practically impossible to construct any piece of apparatus without all three of these properties inherent in electrical circuits. We can, however, approximate a condition of capacity only, or of inductance only, and this is what is done in the case of condensers and coils.

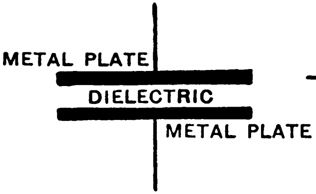


FIG. 1

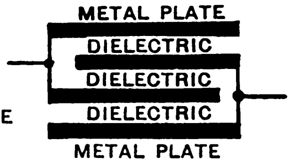


FIG. 2

A condenser, then, is a piece of electrical apparatus in which capacity plays the main role. An effort is made to keep the inductance and resistance so low in value as to render them negligible as compared with the capacity. Generally a condenser consists of a number of metal plates placed near each other, with an electrical insulator between the plates. This insulator may be air, mica, paper, or any substance which offers great resistance to the flow of current from one plate to another.

Varying the Capacity

The capacity of a condenser increases as the overlapping area of the plates increases. It is impracticable, however, to use condensers which have very large plates, for many reasons, which will be brought out later. To obtain a large capacity it is necessary to construct the condenser of several plates connected as shown in Figure 2. This amounts to the same thing as having several small condensers connected in parallel. In a parallel arrangement the total capacity is the sum of the separate capacities.

If several small condensers be connected in parallel, we can vary the total capacity by varying the number of these small condensers in parallel. This is the step-by-step method of varying capacity. Or, if the overlapping areas of the plates in a condenser be varied, the capacity measured at the terminals of the condenser will vary. This is the method employed in the usual variable condenser. The capacity is continuously variable in this case, because it is possible to obtain *any* capacity between maximum and minimum. This is not possible in the first case, in which the capacity can be varied only in steps.

Stray Capacities

It is very difficult to concentrate the total capacity of a circuit at a particular point in the circuit. Every part of the apparatus has capacities to other parts, and these small stray capacities should be taken into account as well as the capacity of the condenser which is intentionally inserted in the circuit. This in many cases is difficult to do, on account of the fact that these stray capacities vary when parts of the circuit or conductors are moved. Moreover, they vary when the frequency of the current is changed, and the effects of the capacities in one part of the circuit may be different from the effects of the capacities in another part.

The disturbing effects may be minimized in practice, as follows: (a) Keeping the condenser a considerable distance away from the conducting or dielectric masses; (b) shielding the condenser, that is, surrounding the whole condenser by a metal covering connected to one plate; (c) using a condenser of sufficiently large capacity, so that the stray capacities are negligible in comparison. The first of these methods reduces the stray capacities of the condenser itself to other parts of the circuit. This is true also of the second method, which is a desirable precaution. One of the chief causes of variation of stray capacities is the presence of the hand or body of the operator near some point of the circuit. Shielding the condenser reduces variations from this cause. The third method is, in general, the best for reducing or eliminating these errors. On account of the stray capacities of its various parts, the whole circuit is in effect a part of the condenser, and their effect is best rendered negligible by making the condenser capacity relatively great.

Causes of Losses

Before going into the discussion of losses, it will be necessary to insure our readers have some understanding as to the terms "power-factor" or "phase-angle." When a current flows in a circuit, this circuit generates reacting or counter forces. In the case of resistance, the counter force is in direct opposition to the flow of current. This is not so in the case of inductances and capacities. In-

ductance furnishes the current with a sort of inertia which makes it **lag** behind the voltage producing it; that is to say, if we imagine the voltage to increase suddenly, the corresponding increase in the current will follow after it instead of accompanying it. In the case of capacities, the current **leads** the voltage. Thus, we may imagine a boy beginning to push a barrel down hill. After he gets the barrel started, its weight causes it to run away from him.

The converse is also true; the current decreases **after** a decrease of voltage in an inductive circuit, and decreases **before** the voltage in a capacitive circuit. If the increase or decrease of the current takes place at the same time as the increase or decrease in voltage, the voltage and current are said to be **in phase.** Otherwise they are **out of phase.**

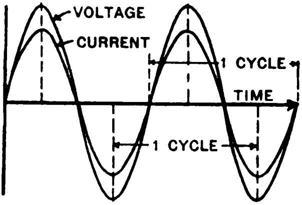


Fig. 3

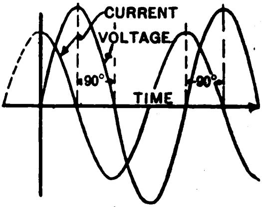


Fig. 4

An alternating current or voltage passes through a succession of values from zero to maximum, back to zero, to maximum in the reverse direction, and then again back to zero. This complete variation is called a "cycle." Half a cycle is called an alternation. Thus in a sixty-cycle circuit the current or voltage has sixty maximums in one direction in one second and sixty in the other, making 120 alternations in all. The current and voltage pass through the zero value between each alternation, or 120 times in a second.

For convenience in calculations, a cycle is regarded as equal to 360 electrical degrees. An alternation is then 180 degrees. Any fraction of a cycle may be expressed in degrees, as 1/10th of a cycle, which covers 1/10th of 1/60th of a second or 1/600th of a second, is equivalent to 1/10th of 360 or 36 electrical degrees. Also, if the current attains its maximum value 1/10th of a second after the voltage attains its maximum, it is said to lag behind the voltage by 36 degrees. The converse is true if the current leads the voltage. Fig. 3 represents the current and voltage in phase. Fig. 4 shows the current leading the voltage by 90 degrees. This is the case of the ideal condenser, in which resistance of plates and connectors is zero, the inductance of the connectors is zero, and dielectric leakage and absorption are zero. (These last two items will be discussed later.)

When the phase difference is 90 degrees, the voltage and current are said to be in "quadrature." In this case the current passes through the zero value when the voltage is a maximum. Fig. 5 shows the current lagging behind the voltage by 90 degrees. This is the case of an ideal inductive circuit.

The difference between 90° and the actual phase-angle of the condenser is the "phase-difference," and is a measure of the imperfection of the condenser. "Power-factor" is the cosine of the phase-angle, and is generally expressed in percentage. The power expended in an alternating-current circuit is

$$P = VI \cos \phi,$$

in which P is the power, V the voltage, I the current, and ϕ the phase-angle. When ϕ is zero, or the current and voltage are in phase, we have $P = VI$, which is the formula that applies to direct-current circuits. The greater the phase-angle the greater must be the current in the circuit to transmit a given amount of power, consequently the greater will be the losses in the circuit which are due to heating, eddy-currents, etc.

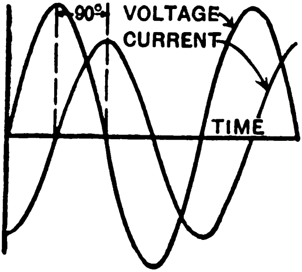


Fig. 5

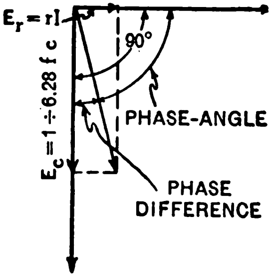


Fig. 6

An alternating voltage in a circuit which contains either inductance or capacity, or both, may be thought of as equivalent to two voltages; one in phase with the current and one in quadrature with it, as represented in the "vector" diagram, Fig. 6, in which E_r represents the voltage drop in the resistance, and E_c the voltage drop in the condenser. The formulas for computing these are given in the diagram. The resistance drop is in phase with the current, and the capacity drop is in quadrature with it. Obviously, the greater the resistance, and consequently the resistance drop, the greater will be the phase-difference and the greater the losses.

The phase-difference is generally represented by ψ, and $\psi = 90° - \phi$. By the rules of trigonometry, $\cos \phi = \sin (90 - \phi)$, or $\cos \phi = \sin \psi$. The above formula may then be written

$$P = VI \sin \psi.$$

This may also be expressed as

$$P = 6.28\ fCV^2 \sin \psi,$$

in which f is the frequency, C the capacity of the condenser, V the voltage across its terminals. This relation shows that for a given voltage, the power loss is proportional to the frequency, to the capacity, and to the phase-difference.

Change of Capacity with Frequency

Another effect of the imperfection of dielectrics is the change of capacity with frequency. The quantity of electricity which flows into a condenser during any finite charging period is greater than would flow in during an infinitely short charging period. Consequently the capacity as measured at low frequencies is greater than that measured at high radio frequencies. The latter is called the geometric capacity, since it can be calculated from the geometrical dimensions of the condenser on the assumption of a perfect dielectric. The capacity of a condenser may change with frequency, due to (a) series resistance in the leads, plates, joints or contacts, (b) leakage or conduction across the dielectric, (c) dielectric absorption. These will be discussed in detail below.

Dielectric Absorption

When a condenser is connected to a source of e.m.f., such as a battery, the instantaneous charge is followed by the flow of a small and steadily decreasing current into the condenser. The additional charge seems to be absorbed by the dielectric. Similarly, the instantaneous discharge of a condenser is followed by a continuously decreasing current. From this it is seen that the value of the charge in a condenser being cyclically charged varies with the frequency of charge.

Dielectric absorption is always accompanied by a power loss, which appears as heat in the condenser. The effect of dielectric absorption may be conveniently thought of in terms of a series resistance, which is generally spoken of as the "equivalent resistance" of the condenser. The equivalent resistance is constant for a given frequency, but is different for different frequencies.

The variation of the power-factor and the equivalent resistance with frequency is a complicated matter, the laws of which are not accurately known. To a first approximation, however, the power-factor of an absorbing condenser is constant. The equivalent resistance is approximately inversely proportional to the frequency.

In the next issue of Radiofax we will discuss more of the technical points in connection with condensers.

REPORT ON THE TEST ON RECTIFIERS FOR BATTERY CHARGING

We will now undertake to obtain a general view of the whole situation of rectifiers for battery charging. We will outline the important items in connection with chargers, so that the student or prospective purchaser will have his knowledge of chargers classified and in usable form.

(1) If a charger rectifies at all, it will charge any battery, providing its output voltage is greater than the counter-emf. of the battery. This feature is provided for in the design of the transformer and is beyond the control of the operator, assuming constant line conditions.

When the output voltage of the charger is less than the counter-emf. of the battery, the battery discharges back into the charger. The proper adjustment of the duration of contact and the transformer secondary voltage is taken care of in the design and is beyond the control of the operator. The points are mentioned, however, as affecting the efficiency of the apparatus and determining whether or not it will do what is required. Any good rectifier on the market will charge an ordinary storage battery.

We will consider here the length of time required to charge a battery. Assume that we start with a fully charged battery lighting three 1-ampere vacuum tubes. If we use these tubes for 4 hours, 12 ampere-hours of electrical energy will have been withdrawn from the battery. A 2-ampere charger will then bring the battery up to charge in 6 hours, while a 6-ampere charger will bring it up to full charge in 2 hours. None of the chargers on the market will do damage to the ordinary lead battery by overcharging. The voltage is not sufficiently high for this, and no harm will result from the slight gassing except that more frequent additions of distilled water will be required. If a 60-ampere-hour battery is totally discharged, the 2-ampere charger will charge it in 30 hours. At any rate, for ordinary usage, any of the chargers are satisfactory, but those having the smaller charging rates will have to be used more often than those having the higher rates, to keep the battery up to charge. This is not generally a disadvantage, however, as other factors enter into the selection of a rectifier, as will be seen below.

(2) We will not enter into a discussion of the initial costs of the various chargers. These will be found in the manufacturers' advertisements, together with the costs of renewal bulbs for the bulb types and vibrating elements and contacts for the mechanical rectifiers. The cost of charging a battery is generally small. This is discussed in the March issue, page 40.

(3) A very important item to consider is whether the charger is self-polarizing. The meaning of this expression is that the polarity of the charger is determined by that of the battery. Self-polarizing rectifiers cannot be connected to the battery in the wrong way. In fact, some of them will not vibrate unless they are connected to the battery. The bulb and electrolytic types are not self-polarizing and care must be taken that they are connected in the proper manner. If connected in the reverse polarity, heavy current flow will take place into the battery in the wrong direction, and if the fuse on the charger does not blow out, the battery is likely to be damaged severely. Chargers that are not self-polarizing have their positive lead that is to be connected to the positive terminal of the battery painted red or marked +.

Chargers which are self-polarizing may not always be able to start a charge on a completely exhausted battery. The voltage of the battery may not be great enough to send through the polarizing coils a current of sufficient magnitude to polarize the vibrator. In this case the charger will not operate. This, however, should not be considered a drawback, as in the case where the battery charge has been so completely exhausted it might be better to take it to a charging station and have it examined and subjected to a good charge at a higher initial rate than can be furnished by the charger. It is very detrimental to the good health of a battery to let its charge run down so low.

At this point we must also consider whether the charger may be allowed to remain connected to the battery after the energizing current has been shut off. Sometimes a vibrating rectifier may stop with its contacts closed, so that after it has been shut off, the battery may discharge through it. This is not possible in some makes of vibrating rectifiers, or in the bulb or electrolytic.

(4) Ease of adjustment of the charger is an important item to consider. An advantage possessed by the bulb and electrolytic type of chargers is the absence of points of adjustments, nor are they necessary in these types. Their presence in the vibrating types, however, leads to flexibility of operation and correct commutation for all charging rates.

In some vibrating rectifiers the adjustment is very broad, and danger of fuse blowing is almost absent, probably due to the small amplitude of vibration of the vibrator. In other chargers the adjustment is extremely critical, the slightest motion of the adjusting screw determining whether or not the charger will charge. Again, the adjustment of some of them is a complicated matter, due to the multiplicity of adjusting points, the misadjustment of any one of them resulting in a motionless vibrator or blown fuse. The proper design

of the vibrating element is therefore an extremely important point, involving the elasticity of the vibrator and its natural period of vibration.

(5) The fifth item on the list is closely allied with the one preceding as well as the one following. Sparking at the contacts depends upon the degree of perfection of the rectification, or, as we might call it, the efficiency of rectification. This latter term must not be confused with the one discussed below, which is the power efficiency of the charger. Adjustment for little or no sparking at the contacts can be made by the operator, and it is obvious that the less the sparking the longer the life of the contacts, as well as the permanence of their adjustment and the fewer the renewals.

(6) As regards the efficiency of chargers, plenty has been said before to give the reader the right point of view. The power efficiency is the efficiency that we are interested in, for it is the power that we have to pay for. This, of course, depends upon the efficiency of rectification. However, it has been shown that high efficiency is not the only feature in a charger that is desirable, a proper balance of the items discussed above being far more desirable than a high efficiency with few other redeeming features.

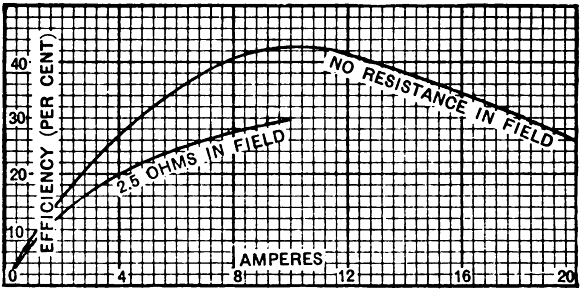
In conclusion we may say that we feel highly gratified with the results of this test. Many things have been learned about rectifiers, and judging from the letters we receive from our readers we feel that they also appreciate the value of this work. The manufacturers as well as the readers are highly pleased, not excepting even those who were the cause of the test. On account of the great popularity that Radiofax has acquired through this test and the respect it has gained through bringing to light the truth about rectifiers, we have started another comprehensive test on condensers for radio receiving. Mention is made of this elsewhere in this issue. Our readers will find this study just as valuable, if not more so, than the last.

There is one other point to consider: what the reader has learned in this test will enable him to distinguish a good charger from a poor one, but not a good one from a very good one. Moreover, not even a psychist could pass judgment on a charger lying idle on the dealer's counter. Let us urge our readers to insist that the dealer put the charger in operation on a battery load before making the purchase. By applying the knowledge learned above, the purchaser will then not go far wrong in his selection.

The Motor-Generator

Considered as a rectifier for battery charging, the motor-generator is in a class by itself, since its operation does not depend upon any special appliances, such as a vibrator, valve-metal or hot cathode.

Some of the characteristics of an M.G. set for battery charging were discussed in the November issue of Radiofax. The figure gives the overall efficiency curve of a machine that was run in the test. The current tapers but slightly during the charge, so that this curve may be taken to represent a pencil of curves close together, each one being the efficiency curve for a different state of charge of the battery.



By adjusting the generator field current the charging rate can be accurately regulated at any state of charge of the battery from zero to full load. If the voltage of the generator is held constant, the delivered current will naturally taper, and it is possible to hasten the charge by using higher rates than are generally obtainable with other types of chargers. Little attention is required, but if the charge is to continue overnight, care must be taken that the initial charging rate is not too high. If the charge is started at a high rate and allowed to continue at this rate as the battery charges up, it will later be found to result in excessive gassing. A rate of about 8 amperes is sufficient to charge up a 60-ampere-hour battery overnight, counting this about 8 hours.

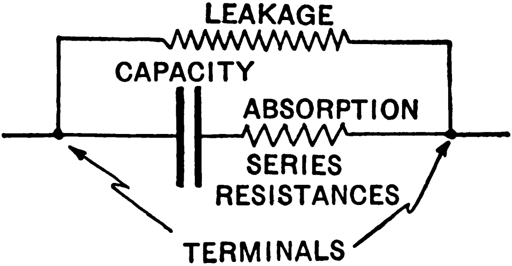
The effect of the resistance in the field circuit is shown in the figure. The resistance not only introduces rI^2 losses in the resistance, but reduces the generated voltage, on account of the diminution of the field strength. The efficiency suffers considerably as a result of this; the most efficient way to charge a battery is to use as high a charging rate as is safe and reduce this at intervals according to the state of charge of the battery. Starting a 60-ampere-hour battery on 20 amperes, this may be continued for 2 hours. There will then be in the battery 40 ampere-hours of charge, that is, 20 ampere-hours are still required. The rate may then be reduced to 10 amperes for 1 hour, and so on, until the battery is completely charged.

Resistances also occur in the joints between the plates and the shaft or posts to which they are attached. Good design requires that such joints be soldered, not only for the purpose of reducing the resistance, but for preventing the plates from moving out of alignment with one another.

Parallel Resistance

Besides these effects mentioned above, a loss of power may be occasioned by the leakage of current across the surface of the dielectric between the plates or terminals. This may be due to absorptive power of the dielectric for moisture. The greater the absorption of moisture the greater will be the conductivity of the surface, and consequently the greater the leakage of current from one set of plates to the other.

It is possible also for current to flow through the body of the dielectric. The value of this current is extremely small, however, since materials of very high volume resistivity are generally used. These two leakage currents are measured together, and the effect is spoken of as the "leakage conductivity" of the condenser. It may be represented by a resistance in parallel with the condenser, and hence is spoken of as the parallel resistance of the condenser.



Effects of Inductance of Leads

In making the connections inside the condenser case from the binding posts to the plates, wire, of course, must be used, and this possesses a small amount of inductance. Care must be taken that these leads are as short as possible, so that the inductance is not appreciable. The presence of inductance of any appreciable amount makes the apparent capacity greater than it would be if the inductance were not present. Moreover, it changes with the frequency, which is not a good thing, since we require condensers whose capacity is constant.

The Ideal and Actual Condensers

As we have mentioned in the preceding issue of Radiofax, the ideal condenser has capacity only. In the

actual condenser we have all the effects that have been mentioned immediately above, viz., dielectric absorption, surface and volume leakage, series resistance, inductance of leads, etc. The actual condenser may be represented as shown in the figure, the series resistance representing the resistances of the plates, leads, contacts and dielectric absorption, and the parallel resistance representing the surface and volume leakage.

Apparent Capacity

As we have intimated in the previous issue, the capacity of a condenser does not remain constant as the frequency varies. The amount of variation depends upon all the different items discussed above—more particularly upon the losses in the condenser, which these things represent. For the case of an absorbing condenser having extremely high leakage resistance (or very low leakage conductance) the phase difference is given by

$$\psi = 0.36\ f r C = 107{,}900\ \frac{rC}{\lambda}$$

in which ψ is the phase difference in degrees, f is the frequency in kilocycles, r is the "equivalent resistance" of the absorbing condenser, C is its geometric capacity in microfarads, and λ is the wave-length in meters corresponding to the frequency f. The determination of the phase difference involves the measurement of the three quantities f, r, and C at the frequency at which the phase difference is required.

The apparent capacity of an absorbing condenser is given by the formula

$$C_a = \frac{C}{1 - \frac{\psi}{57.3}}$$

in which C_a is the apparent or measured capacity at any frequency, ψ is the phase difference in degrees at the same frequency, and C is the geometrical capacity. This formula shows that the apparent capacity of an absorbing condenser is greater than the geometric capacity at all frequencies less than infinite frequency, and decreases to the value of the geometric capacity at infinite frequency. The discussion of these points will be continued in the next issue of Radiofax. The formulas given above neglect the effect of the parallel or leakage resistance, which in the ordinary variable air condensers and in many mica condensers is extremely high and incapable of accurate measurement. As a matter of fact, it is probable that the series resistances of most of the air condensers on the market is very low, so that the measurement of these quantities is an extremely difficult problem, and one in which extreme care must be exercised in interpreting the results of the measurements.

RADIO CONDENSERS

SORTING THE GOOD FROM THE BAD

(Continued from May issue of Radiofax)

In the two previous issues of Radiofax an outline of the various points of interest in connection with condensers for radio receiving purposes was given, primarily as an introduction to a practical study of the condensers on the market. Before going further it will be well to discuss some of the important types. These may be classified somewhat as follows:

1. Fixed	2. Discontinuously Variable	3. Continuously Variable
(a) air	(a) air	(a) air
(b) mica	(b) mica	(b) oil
(c) paper	(c) paper	(c) special designs
(d) oil	(d) oil	

Fixed condensers are either of the flat-plate type or the rolled type. In the former case the plates are flat and are separated by a dielectric, such as mica, air, paper, oil, glass, etc. Oil and glass condensers are generally used in radio for transmitting purposes, the receiving condensers being confined to the air, mica and paper types. Mica condensers are usually of much better quality than paper condensers, but even the best mica condensers do not approach as nearly to ideal condensers as do air condensers. If properly constructed, a mica condenser is only slightly influenced by temperature or other external conditions. They do show dielectric absorption, however, but the effective capacity and phase-angle are perfectly definite, and hence they can be satisfactorily used for many purposes.

In the silvered-mica condensers, the thin sheets of mica are coated with a layer of silver in the manner used in coating a mirror. After removing the silver for a distance of about a centimeter from the edge, the sheets of silvered mica are laid up with sheets of tin-foil between them, and after clamping securely, the whole is impregnated with paraffin or other insulating material, to prevent leakage around the edges. The tin-foil and mica condensers are made in the same way, except that the coating of silver is omitted and the insulating material is invariably paraffin. With these condensers it is important that all air and moisture be removed, so that they are impregnated with paraffin either by boiling in paraffin in a vacuum or at atmospheric pressure. In this way the paraffin forms a layer between the tin-foil and mica, so that the dielectric consists of both mica and paraffin.

In a paper condenser the dielectric consists of a high-grade paper which is impregnated with some insulating material, usually paraffin. The condenser may be

built up by using alternate layers of tin-foil and paper in a manner similar to that used in making mica condensers, or only two large sheets of tin-foil between which are inserted one or two thicknesses of paper may be used, and the whole rolled or folded together.

A paper condenser generally shows greater absorption than a mica condenser. With the best paper condensers this is not materially larger than with the poorer mica condensers, but in some cases it becomes very large. Such condensers have very indefinite values when used under varying conditions of frequency and voltage. The one thing that distinguishes a condenser with a solid dielectric from an air condenser is the absorption which the former show.

Discontinuously variable condensers are simply those which are varied in steps; they consist of a number of fixed condensers encased together with appropriate switching arrangements, provided for cutting them in and out of the circuit. These are often used for transmitting, but seldom if ever for receiving.

Continuously variable condensers are those which can be set to any capacity whatever between the maximum and minimum values. Variable condensers are extensively used, because most radio work involves a variation of either inductance or capacity, and it is difficult to secure sufficient variation of inductance without variation of resistance and capacity in the circuit. The most familiar type of variable condenser has air for its dielectric. The plates are semicircular, one set of which can be revolved, bringing the plates in or out from between the plates of the fixed set. The capacity of a condenser is proportional to the overlapping area of the plates. In a variable condenser of the semicircular type the overlapping area of the plates is changed by rotating the movable plates, and, neglecting the edge effects, is proportional to the angle of rotation. As a result, the capacity is approximately proportional to the setting throughout a wide range, provided that the condenser is well constructed and the distance between the two sets of plates is not affected by the rotation of the movable set. Figure 1, below, shows a typical capacity curve for such a condenser. The intersection of the curve with the axis of ordinates (at "A") is the minimum capacity of the condenser. The maximum capacity is shown at "B."

Condensers are sometimes made with plates of other shapes for special purposes. The frequency or wave length of an oscillating circuit is proportional to the square root of the capacity, so that if the wave length or frequency is plotted against the setting of a semicircular condenser, we will obtain, not a straight line, as shown in Figure 1, but a parabola. If the condenser were calibrated in meters, then the scale would be very

crowded at one end and much elongated at the other. For this reason, in some condensers the plates are made of such shape that the overlapping area, and hence the capacity, is always proportional to the square of the

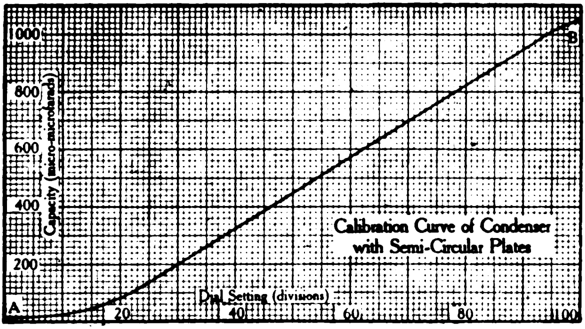


Fig. 1

angle of rotation of the movable plates. In the condenser as actually made, the fixed plates may be semicircular and the movable plates given the required shape as shown in Fig. 2. The overlapping area is the projection of the movable plates upon the fixed ones.

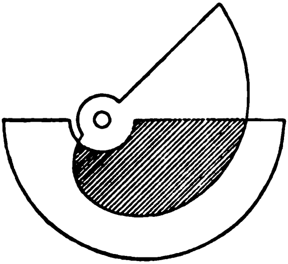


Fig. 2
Shape of Plates of Straight Line Condenser

In any condenser it is required that the capacity remain constant and definite. These conditions require rigidity of construction. The pointer and movable plates must be securely fastened to the shaft, so that no relative motion is possible. Particular care must be exercised in insulating the movable plates from the fixed. The insulating material must be the best, and none should be so placed that it is in the electrostatic field of the condenser. The suspension of heavy plates from a material which may warp is objectionable. The leads inside a condenser should be as short as possi-

ble and their inductance a minimum, since the apparent capacity of a condenser at high frequencies will increase with the frequency, due to the inductance of the leads, in a manner similar to the variation of inductance of a coil with distributed capacity. The resistance of leads and plates and contact resistances between the individual plates and separating washers should be kept as low as possible, in order to minimize the equivalent resistance and the phase-angle.

It is difficult for a manufacturer to take care of all these important points in building his condenser, since all these things represent an expenditure of money on his part and a consequent increase in the cost of the condenser to the radio fan. A compromise between price and quality is necessary as well as a consideration of ease of handling and the space occupied by the condenser. For these reasons, many types of variable air and mica condensers have appeared on the market which serve many purposes in radio receiving outfits very well. The principle on which these special types work is more or less the same. They all employ the principle of moving one plate up to another, having a sheet of mica between them. Figure 3 is a diagrammatic sketch of one type in which the elasticity of one of the plates is employed to make it bend away from the other plate as the screw is backed out. In another type the two plates are arranged to work in book fashion, so that an increase of angle between the two plates decreases the capacity of the condenser. There is still another type of variable condenser with solid dielectric which employs a plunger of brass which works through a screw into a tube partially filled with mercury. The plunger is coated with some kind of insulating material and forms one of the electrodes (or plates) of the condenser, and the mercury forms the other electrode. (Figure 4.) The main objection to this type is that it must be used in the vertical position only.

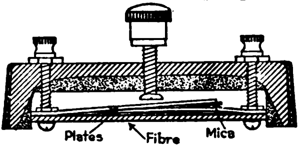


Fig. 3

In the next issue of Radiofax we will discuss the actual values of the capacities of condensers on the market. The methods used in the measurement of capacity will be given, followed by a table of condensers made by the larger manufacturers giving the capacity at 5 different settings, including the maximum and minimum capacities.

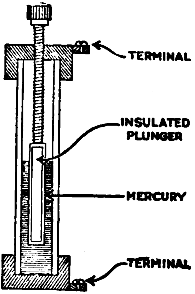


Fig. 4

OSCILLATION AND REGENERATION

The thermionic vacuum tube is inherently an amplifier, due to the slope of its characteristic curve. That means, if we suppose one unit of power were sent into the grid circuit of the tube (i.e., the input side) we might be able to obtain from the plate circuit (the output) six, eight, ten, or more times as much power. It is evident that if we take a little of this power and send it back again through the tube—return it to the input side—this small amount of power may be amplified as before and go to reinforce the original output power.

There are several ways in which the "feed-back" of power from the plate circuit to the grid circuit may be accomplished. One method is by means of the "tickler coil." Another method is to use the internal capacity of the tube as a coupling condenser between the circuits. Another is to use a third circuit coupled inductively to both the plate and grid circuits. No matter what method is used, the results are the same, the only difference being in the numerical value of the quantities involved.

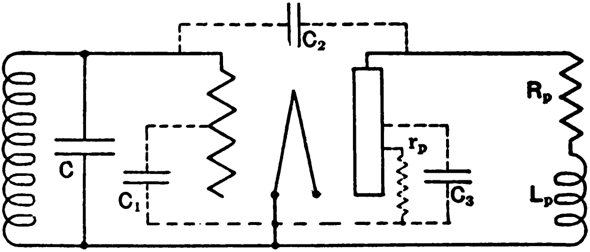
The capability of a circuit to oscillate depends upon the relation of the grid impedance of the tube with the load in the output circuit. It can be shown mathematically that the input or grid impedance can be represented by a resistance and a capacity in series. The tube is thus not a pure voltage device, but absorbs power. The amount of power absorption is determined by the values of the current in the circuit and the apparent grid resistance. Moreover, this grid resistance may be made to disappear under certain conditions, or even to assume a negative value, in which case, the circuit, instead of absorbing power, will furnish power to the circuit. This is the case of oscillation. The value of the grid resistance depends upon the values of the various capacities in the circuits.

There are three internal tube capacities to consider. These quantities are illustrated in the figure. There are several cases to consider. The first will be that in which the load in the plate circuit is a pure resistance. In this case the grid resistance is positive, and hence the input absorbs power even when the grid is negative with respect to the filament. The apparent grid resistance decreases quickly as the frequency becomes greater and greater. This approach to zero resistance, due to the high frequency, added to the effects of any inductance that may be present in the plate circuit, explains the tendency of circuits carrying high-frequency currents to oscillate.

When the plate circuit load is either purely resistive or capacitive, the grid resistance is positive and the grid circuit absorbs energy. No oscillation or regeneration

then occurs. Thus the presence of phones in the plate circuit may cause a dissipation of power in the input, because of the phones having a capacity reactance at high frequencies. For the case of a pure resistance load, the apparent grid capacity is the equivalent capacity of C_2 and C_3 in series and paralleled by C_1, that is, as if the plate circuit were open.

For the case of an inductive load in the plate circuit, the apparent grid resistance will be negative and tend to neutralize the grid circuit resistance; that is, it will regenerate. This explains the regenerative effects in amplifiers, which can occur even when there is no electrostatic or electromagnetic coupling between the



input and output circuits other than through the tube itself. The value of the grid resistance for an inductive plate circuit load is given by

$$r_g = -\frac{L_p}{r_p}\,\frac{(\mu C_2)}{(C_1 + C_2)}$$

in which r_g is the apparent grid resistance, r_p is the internal plate resistance, L_p is the inductance in the plate circuit, and μ is the amplification factor of the tube. The apparent grid capacity is merely $C_g = C_1 + C_2$.

If the external resistance of the plate circuit is very large, the case may arise in which no inductive load can make the resistance negative, in which case no regeneration will occur. The apparent resistance is reduced as a result of the regenerative action, and when r_g and c_g are such as to completely neutralize the resistance of that circuit, oscillations will take place. The reduction in resistance is given by

$$\Delta R = \frac{\mu L_p C_2}{r_p(C + C_1 + C_2)_2}$$

in which ΔR is the reduction in the value of resistance in the grid circuit. The regenerative effects are increased by increasing L_p, decreasing C, or by connecting a small condenser between grid and plate, so as to increase C_2 when C_2 is small compared to C. Sets having a tendency to oscillate may be stabilized by connecting a resistance in the plate circuit.

THE APERIODIC PRIMARY CIRCUIT

A type of receiving circuit which came into popular favor recently is the aperiodic or untuned primary circuit. The name is derived from the fact that the primary inductance does not respond to any particular frequency, except the one to which the antenna circuit naturally tunes. In its most common form, the tuning device consists of a small number of turns wound directly over a coil of many more turns. A condenser shunts the larger inductance, which is placed in the secondary circuit. The small coil is placed in the antenna circuit. As can be seen only one tuning control is necessary. This arrangement was originally designed to eliminate more than one tuning control. The reader can readily see that this is not the most efficient device, as far as the energy received is concerned. The secondary circuit is affected by the energy of the primary circuit, and this can only give its maximum effect when the primary is resonant with the frequency desired. However, it must be noted that with a small coil in the primary circuit there is very little loss in energy, and hence the circuit tunes very sharply.

In the mathematical analysis of the aperiodic circuit, two conditions of coupling will be treated. The one is a very loose coupling, and the other a coupling as close as it is practicable to obtain. For a loosely coupled circuit the effect of the primary circuit may be neglected and the equation for resonance is given by

$$f = \frac{159.3}{\sqrt{L_2C_2}}$$

where L_2 is in microhenries and C_2 in microfarads. f is the resonant frequency, and is given in kilocycles. The curves in Fig. 1 show exactly what size inductance with a given condenser is required to tune in frequencies of the broadcast range. The condensers now available are as follows:

	Maximum Capacity	*Minimum Capacity*
13 plates..........	0.00025	0.000025
17 plates..........	0.00035	0.000035
23 plates..........	0.0005	0.00005
43 plates..........	0.001	0.0001

These capacities are only approximate, and naturally are different for various makes. The minimum capacity is assumed to be one-tenth of the maximum capacity.

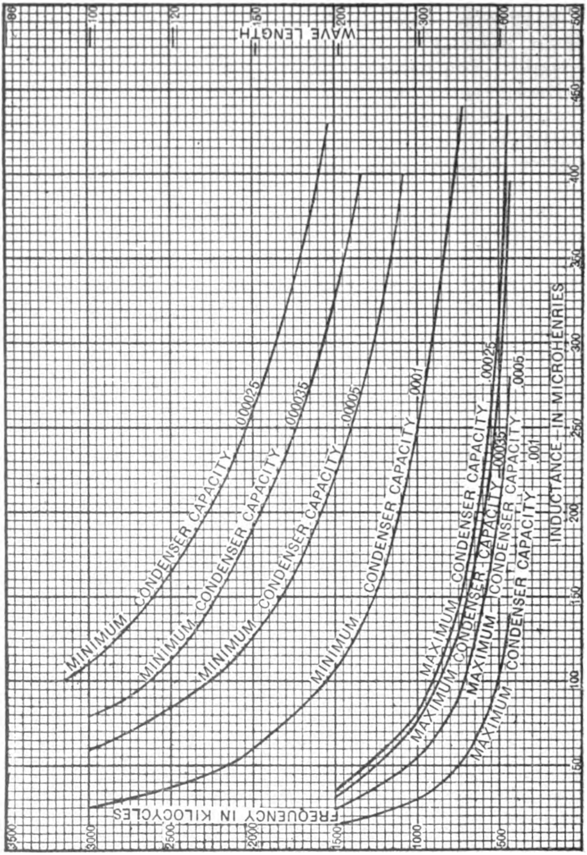


Figure 1

Suppose, as an example, it is desired to receive a range of from 200 to 600 meters with this type of circuit. The primary should consist of a very few turns (about 10), and the size of the secondary depends on the condenser available. From the curves it is seen that with a 0.001 microfarad condenser an inductance of 105 microhenries must be used. A 0.0005 condenser requires an inductance of 200 microhenries. A 0.00035 mfd. condenser requires an inductance of 290 micro-

henries, and a 0.00025 mfd. condenser requires an inductance of 320 microhenries. It must be remembered, however, that these curves apply only to a loosely coupled circuit. The distance between coils may be ¼ inch or more.

We will now study the closely-coupled tuner. The maximum practical coefficient of coupling is about 80%. It is not possible to attain 100% in practice, so in this case we will assume it to be 80%, as representing one of the extreme limits we have chosen.

When k the coefficient of coupling is large (very nearly 100%), the following formula is used for conditions of resonance:

$$\omega = \sqrt{\frac{\omega_1^2 \omega_2^2}{\omega_1^2 + \omega_2^2}} \qquad 1.$$

where $\omega = 2\pi f$ and f is the resonant frequency in cycles

$$\omega_1^2 = \frac{1}{L_1C_1} \text{ and } \omega_2^2 = \frac{1}{L_2C_2} \qquad 2.$$

L_1C_1 and L_2C_2 are measured in henries and farads.

Solving for L_2 we have

$$L_2 = \frac{1}{C_2(2\pi f)^2} - L_1\frac{C_1}{C_2} \qquad 3.$$

The equation in this form discloses one very important fact. The last term may be neglected when L_1 and C_1 are very small in value, and C_2 is relatively large. For instance, a single-wire antenna 75 feet long and 40 feet high has an inductance of about 39.4 microhenries when connected to a coil of 10 turns of No. 24 D.S.C. wire, wound on a 3-inch tube. The antenna capacity is about 195 micro-microfarads. Let us assume a secondary capacity of 0.001 microfarads. The last term of the equation reduces to

$$-\frac{77}{10^{16}} \qquad 4.$$

The ratio is less than one unit in one thousand raised to the fifth power. Hence we need not worry about its effect on the solution.

As a matter of fact, when tuned to a wave length of 400 meters L_2 becomes 50 microhenries, the very same result which is obtained from the curve in Fig. 1. If, however, the primary circuit is tuned and has a large coil in series with a large condenser, the last term of the above equation is not negligible. The result obtained for L_2 is about 50% of the value given above.

Figure 2

The case when both circuits are tuned will now be considered. The equations for resonance reduce to a very simple form.

$$\omega = \frac{\omega_1}{\sqrt{1+k}} \qquad 5.$$

where $\omega = 2\pi f$, and

$$\omega_1 = \omega_2 = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{L_2C_2}} = \frac{1}{\sqrt{LC}} \qquad 6.$$

When f is measured in kilocycles and L and C are given in microhenries and microfarads, respectively, the equation becomes

$$f = \frac{159.3}{\sqrt{LC(1+k)}} \qquad 7.$$

This equation is applicable to both primary and secondary circuits. It will be noticed that when the coupling is very loose, k approaches zero and the equation is identical with the one ordinarily used.

The curves in Fig. 1 may be used for the secondary calculations when k is zero (coils separated by more than ¼ inch). The curves for the antenna circuit are given in Figs. 2 and 3. In this case, a single-wire antenna 50 ft. long and 30 ft. high was assumed. Antenna constants may be calculated from the information given in the October, 1923, issue of Radiofax. The curves given in Figs. 2 and 3 are applicable to a parallel circuit and series circuit. The curves in Fig. 2 cover the ordinary broadcast frequencies, and those of Fig. 3 are for the lower frequencies (higher wave lengths).

In a very closely coupled circuit we assumed k to be about 0.80, hence the quantity $\sqrt{1+k} = 1.34$. The equation now becomes

$$1.34f = \frac{159.3}{\sqrt{LC}} \qquad 8.$$

for both primary and secondary circuit calculations. If an antenna of different dimensions than the one for which the curves were plotted is used, L_1 and C_1 must be adjusted accordingly. For antenna calculations the reader is referred to the October, 1923, issue of Radiofax, pages 11 to 14.

The curves disclose the fact that with a given condenser to cover a certain range of frequencies, less inductance is required in the parallel circuit than in the series circuit. Less inductance means less wire on a given coil, and less wire means less resistance and distributed capacity. Consequently, there is less loss and the tuning is very much improved. The reason for this statement will be given in an article to appear in a later issue.

We will conclude this article with a typical problem in tuning circuit design, and it is hoped that the experimenter will have no difficulty in applying these fundamental principles to his own special case.

Given: An antenna 50 feet long and 30 feet high; a 0.001 mfd. condenser (43 plates), and a 0.0005 mfd. condenser (23 plates).

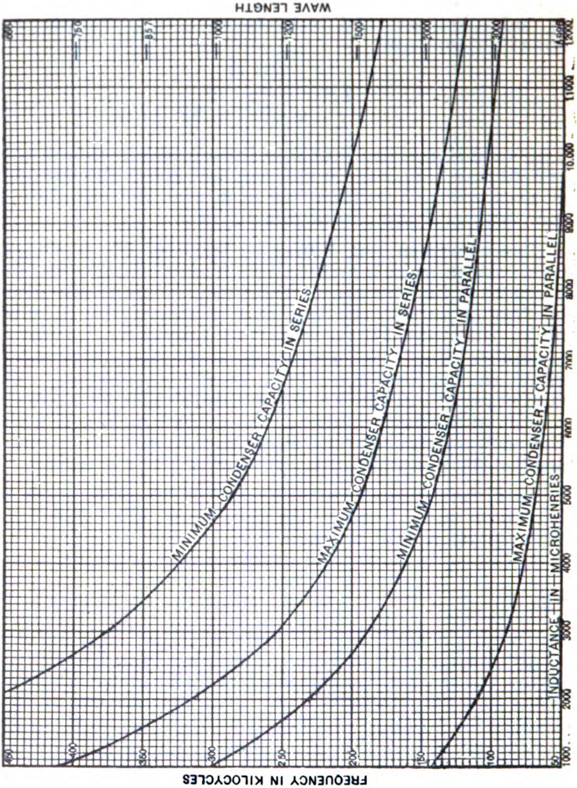


Figure 3

Problem: What size coils shall be constructed to cover a range of 500 to 1,500 kilocycles (200 to 600 meters).

Solution: 1. Aperiodic Primary.

The primary inductance should be very small, say about 10 turns of No. 24 wire on a 3 inch tube. The secondary inductance for use with the 0.0005 mfd. condenser should be 200 microhenries. This solution applies either to a loosely coupled or a closely coupled tuner. The loose coupling sharpens the tuning; the close coupling increases the amount of energy transferred.

Solution 2—Loosely-Coupled, Tuned Primary:

The series circuit in the primary can be calculated from Fig. 2. The use of a 0.001 mfd. condenser requires a variable inductance from 180 microhenries to 780 microhenries. The secondary is exactly as given in solution 1, namely, 200 microhenries. (Neglect the coupling coefficient.)

Solution 3—Closely-Coupled, Tuned Primary:

In this case the coils are assumed to be wound together. Multiply the frequency range by 1.34. The corrected range is then 671 to 2,010 kilocycles. From Fig. 2 we obtain for the 0.001 mfd. condenser a variable inductance of from 90 to 410 microhenries in the primary circuit. Using the same range of frequency in the secondary circuit for the 0.0005 mfd. condenser, we obtain from Fig. 1 an inductance of 130 microhenries. The coil turns may be found in the tables given in the Lefax Radio Handbook, Chapter 5, page 29, or in the September, 1923, issue of Radiofax, page 25.

The experimenter's attention is called to the fact that if a wide band of frequencies is to be covered, a variable inductance must be used in the antenna circuit. The primary parallel circuit evolves much more complicated calculations than does the series circuit. The parallel circuit curves in Figs. 2 and 3 may be used for approximate solutions. In such rough calculations the antenna constants are usually neglected. However, for the experimenter who desires accurate methods of calculating antenna circuits the following issue of Radiofax will be exceedingly helpful.

The method of solution involved is a graphic one and simplifies calculations which are often very complicated. Curves will be drawn for different circuits and combinations of circuits, showing the variation of reactance with frequency. These so-called "reactive diagrams" readily show what effects additions to existing circuits will produce, or exactly what the resonant frequencies for a given circuit are. Reactance diagrams tell in a very simple way at what frequency or frequencies the current is either large or small. They explain the theory of the wave trap, and enable anyone to design his own apparatus without a very complete knowledge of mathematics. In fact, the theory of all resonant and anti-resonant circuits may be easily understood from the reactance diagram.

SUPPLEMENT TO MARCH 12. 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
KFBE	Horn & Wilson's Radioland	SanLuis,Obispo,Cal.	1390	216	50
KFWA	Browning Bros. Co........	Ogden, Utah........	1400	214	500
KUOM	State Univ. of Montana...	Missoula, Mont.....	1230	244	250
WARC*	American Rad. & Research Corporation............	MedfordHillside, Mass............	1150	261	100
WCUW†	Clark Univ. CollegiateDept	Worcester, Mass....	1260	238	250
WHBF	Beardsley Specialty Co....	Rock Island, Ill....	1350	222	100
WHBG	John S. Skane............	Harrisburg, Pa......	1300	231	20
WHBH	Culver Military Academy..	Culver, Ind.........	1350	222	100
WHBI	Chesaning Electric Co.....	Chesaning, Mich...	1320	227	50
WHBJ	Lauer Auto Co.............	Ft. Wayne, Ind....	1280	234	10
WHBK	Franklin St. Garage, Inc...	Ellsworth, Me.......	1300	231	10
WHBL	James H. Slusser..........	Logansport, Ind....	1360	220	50
WHBM	C. L. Carroll (Portable)...	Chicago, Ill.........	1290	232	20
WHBN	First Ave. Methodist Ch...	St. Petersburg, Fla..	1160	259	10
WHBO	Y.M.C.A..................	Pawtucket, R.I......	1300	231	50
WHBP	Johnstown Auto. Co.......	Johnstown, Pa......	1170	256	10
WHEC	Hickson Elec. Co., Inc.....	Rochester, N.Y....	1160	259	100
WKBE	K & B Electric Co.........	Webster, Mass......	1300	231	10

*Old call signal WGI. †Old call signal WCBT.

CHANGES

KDKA	Westinghous E.&M. Co....	E. Pittsburgh, Pa...	970	309	Varia.
KDYL	Newhouse Hotel..........	Salt Lake City,Utah	900	333	500
KDZB	Frank E. Siefert..........	Bakersfield, Calif....	1430	210	100
KFAD	McArthur Bros. Co........	Phoenix, Ariz.......	1000	300	500
KFAE	State College of Wash.....	Pullman, Wash......	860	349	500
KFAW	The Radio Den...........	Santa Ana, Calif...	1400	214	10
KFBK	Kimball-Upson Co........	Sacramento, Calif...	1210	248	100
KFI	Earle C. Anthony, Inc.....	Los Angeles, Calif..	640	469	1500
KFIQ	First Methodist Church...	Yakima, Wash......	1170	256	100
KFKX	Westinghouse E. & M. Co.	Hastings, Nebr......	1040	288	1500
KFLU	San Benito Radio Club...	San Benito, Tex....	1270	236	10
KFOA	The Rhodes Dept. Store...	Seattle, Wash.......	660	454	500
KFPG	Oliver S. Garretson.......	Los Angeles, Calif..	1260	238	100
KFQZ	Taft Radio Co............	Hollywood, Calif....	1330	225	250
KFRC	Radioart Studio..........	San Francisco, Calif.	1110	270	50
KFRU	Etherical Studies..........	Bristow, Okla.......	760	395	500
KGO	General Electric Co.......	Oakland, Calif......	830	361	2000
KHJ	Times-Mirror Co..........	Los Angeles, Calif..	740	405	500
KJR	Northwest Rad. Serv. Co..	Seattle, Wash.......	780	384	500
KLX	Tribune Publishing Co.....	Oakland, Calif......	590	508	500
KLZ	Reynolds Radio Co., Inc...	Denver, Colo........	1130	265	250
KMJ	SanJoaquin Lt.&Pr. Corp..	Fresno, Calif........	1280	234	50
KPO	Hale Bros., Inc............	San Francisco, Calif.	700	428	500
KRE	Berkeley Daily Gazette...	Berkeley, Calif......	1160	259	50
KSD	Post-Dispatch............	St. Louis, Mo.......	550	545	750
WAAB	Valdemar Jensen..........	New Orleans, La....	1000	273	100
WBS	D. W. May, Inc............	Newark, N. J........	1190	252	100
WCAO	Sanders & Stayman Co....	Baltimore, Md......	1090	275	250
WCBQ	First Baptist Church......	Nashville, Tenn.....	1270	236	50
WCBY	The Forks Elec. Shop.....	BuckHill Falls, Pa..	1300	231	30
WDBQ	Morton Radio Supply Co..	Salem, N. J.........	1280	234	10
WDM	Grace Church of the Cov..	Washington, D.C...	1110	270	50
WFAV	University of Nebraska....	Lincoln, Nebr.......	1090	275	500
WFBN	Radio Sales & Service Co..	Bridgewater, Mass..	1330	225	10
WGBA	JonesElec.&Rad. Mfg. Co..	Baltimore, Md.......	1180	254	100
WGY	General Electric Co.......	Schenectady, N.Y..	790	380	1500
WIL	Benson Radio Co..........	St. Louis, Mo.......	1100	273	100
WJAK	Clifford L. White..........	Greentown, Ind.....	1180	254	20
WKAV	The Laconia Radio Club..	Laconia, N. H.......	1430	210	50
WLW	Crosley Radio Corp........	Harrison, Ohio......	710	422	1500
WOAC	Page Organ Co............	Lima, Ohio.........	1150	261	50
WTAQ	S. H. Van Gorden & Son...	Osseo, Wis.........	1180	254	200

Licences Recently Cancelled

KFDL KFQD KFQE WBBD WCBT WEBP WGI WJAB WOAV WRAO

HOW THE CONDENSERS WERE TESTED

The tabulated results of our condenser test have been in the hands of our readers for some time, but a description of the apparatus employed has not heretofore been published. We have withheld these details in deference to Mr. Chas. N. Weyl of the Moore School of Electrical Engineering, University of Pennsylvania, and to Mr. S. S. Harris who was until recently on our editorial staff. To these men we delegated the task of finding a method whereby the equivalent series resistance of condensers could be measured directly at radio frequency. In recognition of their successful solution of this problem, we agreed to delay publication of the method until they had presented it as a paper in the Proceedings of The Institute of Radio Engineers, February, 1925. The following is largely a digest of that paper.

Practically every radio-receiving circuit makes use of the phenomenon of resonance. In a vast majority of cases it is desirable to produce as sharp a resonance as possible, which indirectly means that all losses of power in the circuit must be reduced to a minimum. Since a resonant circuit consists essentially of an inductance (usually a coil of some sort) and a capacity (some type of condenser), it is important that the designer reduce the losses in both coil and condenser as far as is possible.

Much work has been done on the resistance of coils used in radio-frequency circuits, but it has been found that it is almost universal practice to determine losses of receiving air condensers at audio-frequencies, even though the condensers are intended to be used in radio frequency circuits. This means that it has been thought possible, from the equivalent series resistance measured at audio frequency (for example 1 kilocycle) to compute the value for radio frequencies (for example 1,000 kilocycles). If the results of such a transformation are to be of value, the exact law connecting loss and frequency must be known, since the orders of magnitude of audio and radio frequencies are so vastly different. A study of the literature tends to show that these laws are not accurately known and at best would not yield readily to computation.

A brief consideration of the elements which constitute the equivalent series resistance of a condenser will serve to show a few of the difficulties involved, leakage resistance, dielectric absorption, and the resistance of the plates and connections all contribute to the losses in a condenser. All of these factors are subject to variation with frequency. It would be necessary to

know precisely how each of these factors varies with frequency if we desire to compute the effect at one frequency when measurements have been made at another, bearing a ratio to the first 1-to-1,000.

Measurements at Radio Frequencies

The principle upon which the method is based can be explained by reference to Fig. 1. The coil O is supplied with energy at any desired radio frequency by a vacuum tube oscillator. The loop L and the condenser C form a simple resonant circuit. A known resistance r_s is short-circuited by a heavy removable bar S. A is a thermo-galvanometer.

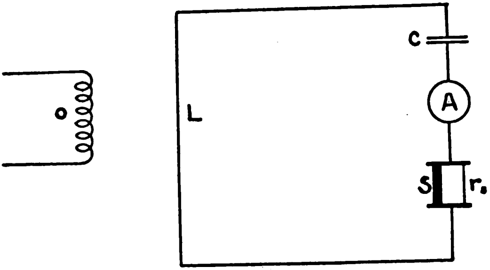


Fig. 1

Suppose that the oscillator is adjusted to give resonance in the circuit LCAS.

If E is the emf. induced in the circuit by O,

r is the resistance of the loop and ammeter.

r_c is the equivalent series resistance of the condenser.

then $I_1 = \dfrac{E}{r + r_c}$ where I_1 is the resonant current.

Now if the bar S is removed and resonance still obtains

$I_2 = \dfrac{E}{r + r_c + r_s}$ where I_2 is the resonant current.

The justification for assuming E the same in both cases will appear later.

From the above equations

$$r_c = \frac{r_s}{\dfrac{I_1}{I_2} - 1} - r$$

If r, r_s, and I_1/I_2 can be accurately determined we have a means of determining r_c.

It is at once apparent that unless r is smaller than r_e, a small error in the determination of the value of r will introduce a large error in the computed value of r_e. Therefore the resistance of the loop and meter must be as small as possible. The ratio I_1/I_2 must also be as large as is consistent with the accurate part of the range of the galvanometer being employed. Further, if the equivalent series resistances of condensers of different capacities are to be measured at the same frequency, a loop of variable inductance must be used.

Preliminary experiments showed that for air condensers having a capacity of the order of magnitude of 500 micro-microfarads, the equivalent series resistance was in the neighborhood of an ohm at 1,000 kilocycles. Therefore it was necessary to make the loop and galvanometer resistance as much less than this as was possible.

A very sensitive thermo-galvanometer having a resistance of about 5 ohms was chosen. This meant, of course, that it was necessary to shunt the galvanometer with a low resistance.

However, reference to article 41, Circular 74, U. S. Bureau of Standards explains the difficulty of employing such shunts due mainly to the impossibility of determining accurately the division of the current between the shunt and the meter. It is to be noted that this difficulty was eliminated in the present method, since the expression for r_e depends upon the ratio of I_1 to I_2 and not upon their absolute values. It was assumed, and later justified, that although the distribution of the current between shunt and meter could not be accurately determined, that for a given frequency the ratio of shunt current and meter current would be the same for different values of total current through the loop.

Since a thermo-galvanometer was used, for a given frequency, the readings of this meter, which had been carefully checked against a standard, were proportional to the square of the current through the loop and condenser.

As a shunt for the galvanometer, a three-inch (7.6 cm.) length of number 14 copper wire was used, which even at radio frequencies had a negligible resistance.

Before building the loop, curves of inductance and resistance per foot for various sizes of copper wire were calculated from formulas given in a paper by Rosa and Grover, Bulletin, U. S. Bureau of Standards, Vol. 8, 1912. The adjustable loop finally chosen (Fig. 2) was made of number 8 B.&S. copper wire and had maxi-

mum dimensions of 17.5 by 25 feet. The resistance of this loop for various adjustments is shown in Fig. 3. With this loop, resonance was obtainable at 1,500 kilocycles for the capacities ranging from 250 to 500 micro-microfarads. At this frequency the total resistance of the loop including leads was calculated to be 0.8 ohm. No advantage could be gained by using heavier gauge wire since the increased diameter of the wire would necessitate the use of a larger loop, because the inductance of a loop of given dimensions decreases as the diameter of the wire increases.

However, since the resistance of such a loop can be calculated with great accuracy and since the equivalent series resistance of a 250 micro-microfarad condenser is approximately 2 ohms at 1,500 kilocycles, this loop was quite satisfactory.

It is to be noted that larger condensers which, in general, have smaller resistances, required less loop and consequently r was proportionately decreased.

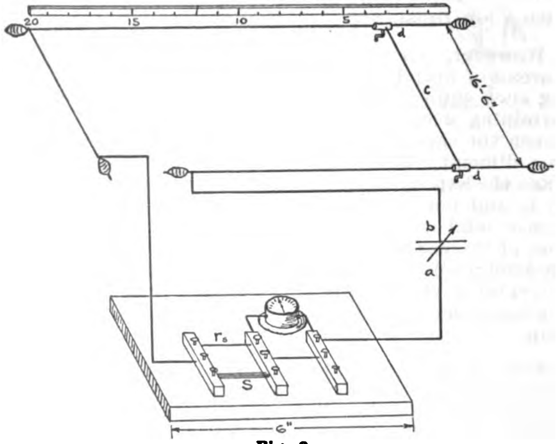


Fig. 2

The resistance r_s (Fig. 2) was a single strand No. 30 B.&S. manganin wire, having a d-c. resistance (measured in place, by a Wheatstone bridge) of 2.10 ohms. Reference to Table 1, Chap. 2, Morecroft's "Radio Communication," will show that the resistance of a manganin wire of less than 0.29 mm. in diameter at 3,000 kilocycles or less, differs by less than one per cent from the d-c. resistance. Manganin was chosen on account of its very low temperature coefficient of resistance.

The short-circuiting bar was made of copper and could be clamped into position by heavy set screws (Fig. 2). It is important to note that the short-circuiting bar and the resistance r_s, were offset with respect to the loop in such a manner as to make the inductance of the loop virtually the same with the bar in or out.

A twenty-watt oscillator was employed with extremely loose coupling to the loop. In this way a negligible reaction took place between the loop and oscillator.

Procedure of Measurement

1. The condenser is connected to the points (a) and (b) (Fig. 2) with short heavy leads.
2. The dial is set at the desired capacity, if a variable condenser is being measured.
3. By means of an accurate wavemeter the oscillator is adjusted to give the desired frequency.
4. With r_s short-circuited by means of bar S the adjustable side, (c) of the loop is moved until resonance is indicated by the thermo-galvanometer. Non-conducting rods should be used to make the final adjustment of the loop in order to avoid body capacity effects. When the exact point of resonance has been found, the clamps (d) are tightened.
5. The output of the oscillator is then adjusted to give approximately full scale reading of the thermo-galvanometer, the frequency being maintained constant, using the wave meter as a check.
6. A reading is taken of the thermo-galvanometer, the observer being careful not to touch any part of the apparatus.
7. The short-circuiting bar S is then unclamped and slid back, introducing the additional resistance r_s into the circuit.
8. A second reading of the thermo-galvanometer is taken.
9. The position of the adjustable side of the loop is noted.

Calculation of Equivalent Series Resistance

Having obtained the ratio I_1/I_2 and the position of the adjustable side of the loop, the calculation of the equivalent series resistance is quite simple. By consulting the curves in Fig. 3, the resistance of the loop and leads are determined at the given frequency. These data are then substituted in equation (1) which yields r_s directly.

Proof of Validity of Method

The equivalent series resistance of a 500 micro-microfarad variable air condenser was measured at 1,500 kilocycles by the method described above. A piece of number 30 B.&S. "Advance" wire was then carefully

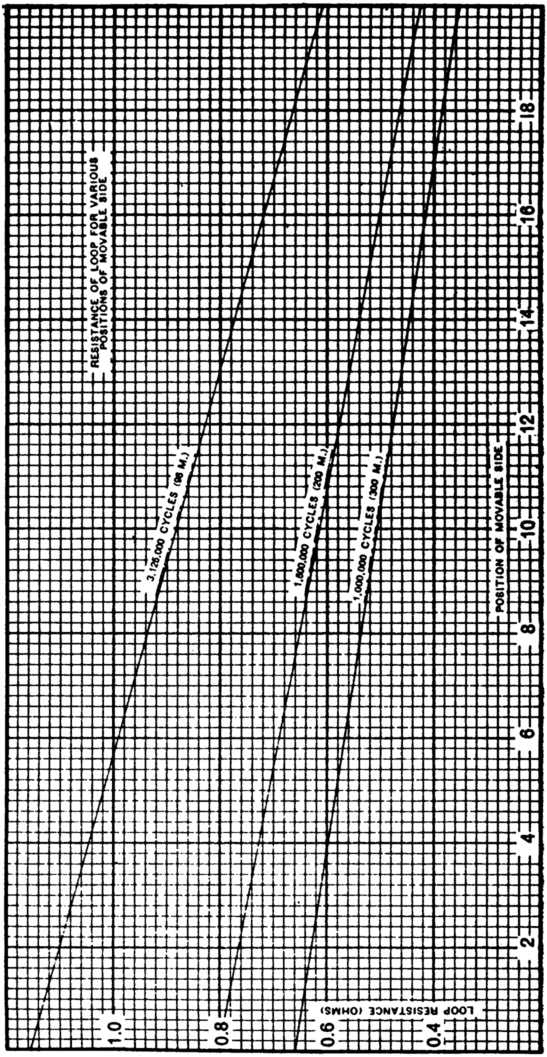

RESISTANCE OF LOOP FOR VARIOUS POSITIONS OF MOVABLE SIDE
3,126,000 CYCLES (96 M.)
1,500,000 CYCLES (200 M.)
1,000,000 CYCLES (300 M.)
POSITION OF MOVABLE SIDE
2
4
6
8
10
12
14
16
18
LOOP RESISTANCE (OHMS)
1.0
0.8
0.6
0.4

Fig.3

soldered between two heavy copper lugs. A careful measurement by means of a Wheatstone bridge yielded a resistance of 0.775 ohms for this wire. The wire, with its lugs, was then connected in series with the 500 micro-microfarad condenser and the combined resistance of the condenser and resistance wire was measured at 1,500 kilocycles. The value of r_e was then deducted from the combined resistance of r_e and the "Advance" wire. This yielded a result of 0.796 ohms or a difference of less than 2.7 per cent, part of which difference is accounted for by skin effect. This test was repeated for several known resistances and at several frequencies, the maximum deviation noted being less than 3 per cent.

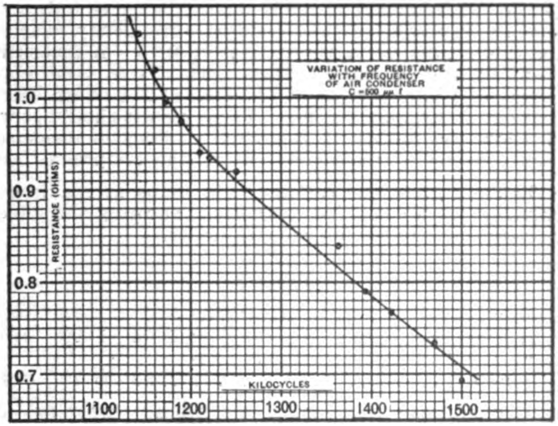


Fig. 4

A series of tests were also made to determine the effect of different loop and oscillator couplings, and also different values of r_e varying from 0.56 ohms to 2.12 ohms. The deviation from the mean of the values was less than 3 per cent.

The effect of foreign metallic bodies in the region of the apparatus was also determined, showing that under the conditions of these tests such effects were entirely negligible.

A careful test was made to determine the effects of any harmonics which might be present in the oscillator output, but the sharpness of the measuring circuit was so great as to render such effects entirely negligible.

Some Results Obtained

The effect of different dial settings on the equivalent series resistance of a condenser was investigated and it was found that the resistance increased very appreciably at the lower part of its range. The frequency was maintained constant for each setting at 3,125 kilocycles. A curve showing this relation of resistance to dial setting was given in Radiofax for December, 1924.

The curve in Fig. 4 shows the variation of the equivalent series resistance of the same condenser with frequency, maximum intermesh of the plates being maintained throughout the test. The regularity of the points is further evidence of the precision of the method. When these same data are plotted on logarithmic paper, (while the frequency range is small) the curve indicates that the exponent of the resistance—frequency relation for this condenser is approximately 0.76. A measurement by the Bureau of Standards of this same condenser at 1 kilocycle yielded a result of 278 ohms which justifies an exponent of 0.7. These results should serve to show the fallacy in referring 1 kilocycle measurements to radio frequencies, using the reciprocal law.

Table 1 gives the resistance in ohms at maximum capacity for a set of six condensers showing the effect of enclosing condensers in metal cases.

Table 1

Approx. capacity micro-microfarads	270	515	1075
r_e at 1,500 kilocycles with containers	2.02	1.00	0.57
r_e at 1,500 kilocycles without containers	1.53	0.79	0.45

A condenser (800 micro-microfarad capacity) of standard make having solid bakelite end plates was measured at 1,000 kilocycles. The end plates were then drilled, leaving only a supporting skeleton of bakelite. A new measurement was made. A pigtail was then added. A third measurement of resistance was made, the results in ohms of these measurements were as follows:

Solid end plates, no pigtail	0.85
Skeleton end plates, no pigtail	0.81
Skeleton end plates and pigtail	0.73

Complete Results

A tabulation of the values determined for approximately 200 condensers will be found in the July and October issues of Radiofax for 1924. We still have a few copies on hand which may be obtained at the regular price of 25c per copy or 50c for the two issues.

REACTANCE DIAGRAMS

In the March issue of Radiofax we drew curves showing the inductances required for use with given condensers to produce resonance at various frequencies. At the end of the article containing these curves, some statements regarding reactance diagrams were made telling of their simplicity and usefulness in solving radio-circuit problems of all kinds. It is our purpose to begin a discussion of these diagrams in this article, with the hope that the reader will be able to visualize the actual conditions existing in a radio circuit at its resonance point.

Let us take a circuit consisting of a coil of wire having both resistance and inductance and apply a d.-c. voltage to its terminals. If we know the value of the voltage and measure the current through the coil, we can obtain its d.-c. resistance. This resistance measured in ohms is given by the formula

$$R_{D.C.} = \frac{V_{D.C.}}{I_{D.C.}}$$

The subscript d.-c. indicates that the measurements were made with direct current. If, however, we apply a known alternating voltage to the circuit and then calculate the resistance by the above formula, where I is the measured value of the alternating current in amperes, we obtain a number higher than the first one. Moreover, if we increase the frequency of the alternations we find that this quotient increases. This number evidently is composed of the d.-c. resistance and another factor which depends on the frequency of the applied voltage. The a.-c. voltage divided by the a.-c. current is called impedance. This impedance is made up of two components, one called "resistance" and the other called "reactance." The relation between impedance resistance and reactance is given by $Z = \sqrt{R^2 + X^2}$ where Z = impedance R = resistance and X = reactance. Impedance resistance and reactance are all measured in ohms. It is found that the reactance X varies with frequency, according to the following relation:

$X = 2\pi fL$ where X = reactance in ohms f = frequency in cycles, L = inductance in henries and π is the number 3.1416. We can see that reactance depends upon frequency and inductance. All coils have resistance and inductance and hence reactance. The resistance dissipates the energy flowing through it in the form of heat. Such energy cannot be recovered. Reactance stores energy in a magnetic field and can be recovered. It is better, therefore, to keep the resistance as low as possible for maximum energy to be used to advantage.

If instead of the circuit just mentioned we have one containing resistance inductance and capacity in series a peculiar effect is noticed. We may impress an alternating voltage across the circuit and notice the reading of an ammeter in series with the resistance inductance and capacity. If we vary the resistance the current will change. An increase in resistance brings about a decrease in current. But we may vary the inductance or the capacity so that the current increases at first, reaches a maximum value and then decreases again. At the maximum point it is found that the quotient

$$\frac{V}{I}$$

gives the d.-c. resistance of the circuit, but that at any other current reading $\frac{V}{I}$ is greater than the d.-c. resistance. Evidently the condenser produces an effect on the circuit which neutralizes the effect of the inductance and causes the circuit to act as if it possessed resistance only. In order to have maximum current through the circuit the resistance must be reduced to a minimum.

The inductance affects the circuit only by its reactance and the only way to neutralize this reactance is to connect an equal negative reactance in series with it. The condenser is found to have negative reactance with respect to the inductance, and at the point where maximum current flows through the circuit the reactance of the condenser just neutralizes the reactance of the inductance. In other words, $X_L - X_C = 0$ where X_L = inductive reactance and X_C = condensive reactance. This phenomenon is known as "resonance." It is found that condensive reactance consists of the following elements:

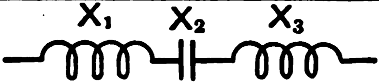
$$X_C = -\frac{1}{2\pi fC}$$

where f is frequency and C is capacity. X_C is given in ohms when f is in cycles per second and C is in farads. As for inductive reactance, X_L is given in ohms when f is in cycles and L is in henries.

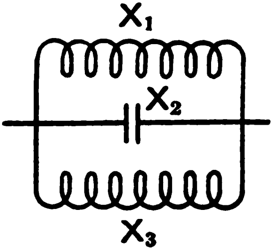
For simplicity let us express X_L as ωL instead of $2\pi fL$ and X_C as $-\frac{1}{\omega C}$ instead of $-\frac{1}{2\pi fC}$, that is let $\omega = 2\pi f$. The reactance of a series circuit is the sum of the reactances of the separate units. In Fig. 1_a $X = X_1 + X_2 + X_3$ where $X_1 = \omega L_1$, $X_3 = \omega L_2$ and $X_2 = -\frac{1}{\omega C}$

The reactance of a parallel circuit is given by

$$\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3}$$ as shown in Fig. 1_b.



1 (a)



1 (b)

The reactance diagram of a coil is a curve showing the variation of X_L with ω and hence with frequency. The reactance diagram of a condenser is a curve showing the variation of X_C with ω. The reactance diagram of a circuit composed of inductances and capacities is a curve showing the variation of the total reactance X with ω and hence with frequency. Let us choose a coil of inductance 200 microhenries (200 microhenries $= 200 \times \frac{1}{10^6}$ henries). Most inductances in radio circuits are measured in microhenries. The broadcast range of frequencies is from one-half million cycles up to one and one-half million cycles, or from 0.5×10^6 cycles up to 1.5×10^6 cycles. Since $\omega = 2\pi f$ or $6.28f$ we may say that ω varies from 3.14×10^6 up to 9.42×10^6. Then when plotting a reactance diagram for the broadcast range we will plut ω between 0 and 10×10^6, and the diagram will include all frequencies from 0 to 1.5×10^6 cycles per second.

We will now make a table from which we will plot the diagram for the coil selected: $L = 200 \times 10^{-6}$ henries.

$\omega = 0$	2×10^6	4×10^6	6×10^6	8×10^6	10×10^6
$\omega L = 0$	400Ω	800Ω	1200Ω	1600Ω	2000Ω

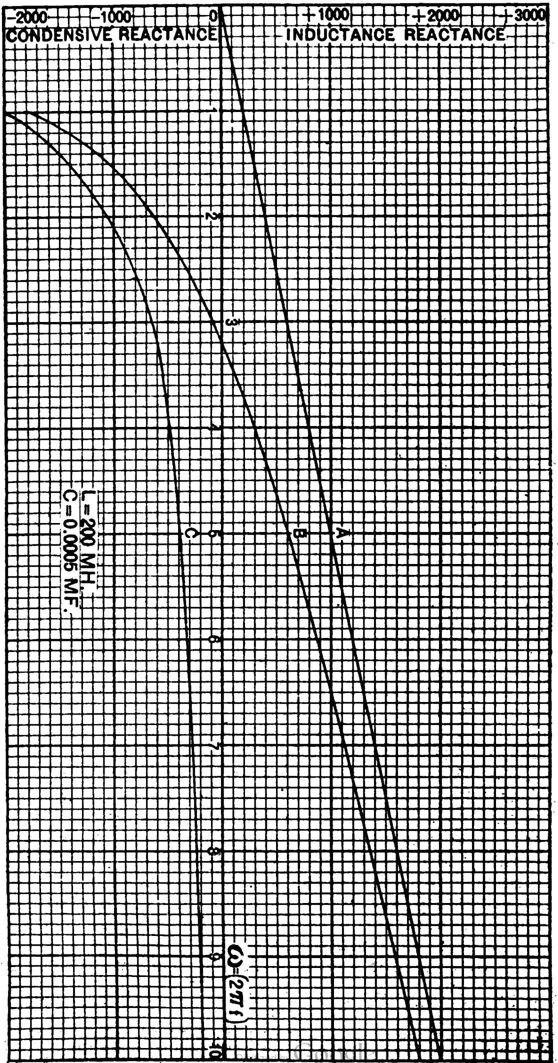
Note: When $\omega = 6 \times 10^6$ then $\omega L = 200 \times 10^{-6} \times 6 \times 10^6$ or 1,200 ohms. The symbol for ohms is Ω. This diagram is a straight line passing through the origin where $X = 0$ and $\omega = 0$, as shown by curve A in Fig. 2. Hereafter then, in plotting the reactance diagram of an inductance we need select but one point, say $\omega = 10 \times 10^6$ and find the corresponding ωL. A straight line drawn through the origin and this one point will be the complete diagram for the coil.

The diagram for a condenser is a little more difficult. We know that $X_C = -\frac{1}{\omega C}$ hence we choose several values of ω, substitue them in this formula and solve for

X_C. We will choose a capacity of 0.0005 microfarads and make up a table as above.

$\omega =$ 02 $\times 10^6$ 4×10^6 6×10^6 8×10^6 10×10^6

$-\frac{1}{\omega C} = \infty$ $-1{,}000\Omega$ -500Ω -334Ω -250Ω -200Ω



CHAPTER FIVE

PRINCIPLES OF RECEIVING AND TRANSMITTING APPARATUS

In chapter 4 an explanation was given of the general processes by which radio is carried on. The present chapter explains the action of the various parts of the apparatus used. It gives the "how" or "why" of the devices whose operation was described in Chap. 2. A few paragraphs are also devoted to transmitting apparatus, for the general information of the user of receiving apparatus. This book does not attempt a complete discussion of transmitting apparatus.

The Antenna.—The radio waves are produced by alternating current which flows in the circuits of the transmitting station, and these waves are converted back into alternating current in the circuits of the receiving station. That is, electrical vibrations produce electric waves which spread out in all directions and these waves are capable of producing electrical vibrations again in any circuit which they pass. The device which converts the electric vibrations (alternating current) into electric waves, or which converts the waves back into alternating current is the antenna. The antenna really has a large job to do, and for all that, it is nothing but a piece of wire.

The antenna is simply an enlarged portion of the circuit. As previously explained, radio circuits consist of two principal elements, called capacity and inductance. A circuit containing capacity and inductance naturally responds to some particular frequency of alternation of electric current, just as a vibrating bell or tuning-fork has some natural frequency of vibration. The "capacity" is the electrical quality that corresponds to the elasticity or springiness of the tuning-fork, and the "inductance" corresponds to its inertia or mass. Now the antenna can be either one of these two elements, the capacity or the inductance. In most radio stations, it is the capacity. It consists essentially of two electrical conductors with air between. One of these conductors is an elevated wire, or set of wires, while the other conductor can be either a similar set of wires or else the ground. A typical circuit in which the antenna thus constitutes the capacity is shown in Fig 1. The other part of the circuit, the

inductance coil, is connected between the elevated wires and the ground.

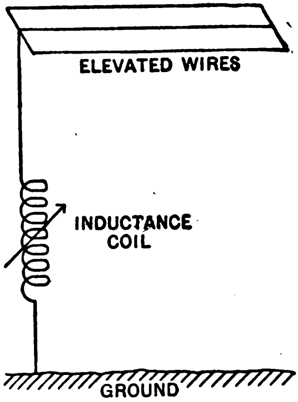


Fig. 1—Simple antenna circuit, with elevated wires and ground constituting a capacity

Just the opposite arrangement is used with a "coil antenna." The inductance coil is made large and constitutes the antenna, and a device possessing capacity (called a condenser) is connected to the two ends of the inductance coil. The arrangement is shown in Fig. 2. The "condenser" consists of two metal plates, or sets of plates, with air or some other non-conductor between.

The simple antenna consisting of elevated wires together with a ground connection is much more commonly used than the coil antenna. The reason is that it gives more powerful signals. For special purposes, however, the coil antenna has advantages, especially in a receiving station. It can be very small, so that a complete radio receiving station can be within an ordinary room. Also, the strength of the signal received on it depends on the direction in which the coil is turned. By turning the coil, therefore, one can determine the direction from which the wave is transmitted. A coil antenna is thus a radio direction finder, it is useful in steering ships and airplanes, and also enables one to prevent interference by turning it so as not to receive the signals from a disturbing station.

Tuning and Coupling.—As explained in the last chapter, radio receiving apparatus must be so adjusted as to be in tune with the wave to be received. The alternating current produced in the receiving circuit will be greater the more nearly this circuit responds to the particular frequency of alternation that the wave has. The circuit is adjusted to respond best to the

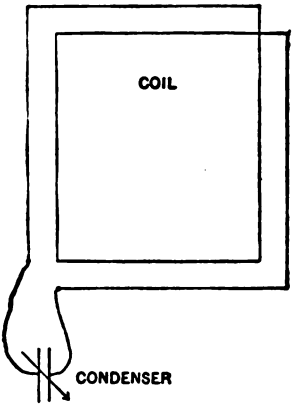


Fig. 2—Coil antenna circuit.

wave by varying either of the two elements, the capacity or the inductance. The process of adjusting the capacity or the inductance is called tuning. When the antenna constitutes the capacity, as in Fig. 1, the tuning is done by means of varying the inductance, and *vice versa* when the antenna is the inductance coil as in Fig. 2 the tuning is done by varying the capacity of the condenser.

The diagrams shown in Figs. 1 and 2 are the foundations of all radio circuits and deserve careful study. Figure 1 in particular should be thoroughly understood, because most radio apparatus is designed for use with the elevated-wire antenna.

Tuning has another object besides getting the strongest possible response from the wave that it is desired to receive, and that is to avoid receiving any other waves of different frequency or wave lengths. It has been found that this is greatly helped by adding another circuit which is also tuned in the same way as the first circuit. The additional circuit also consists of capacity and inductance, and is called the secondary circuit. The process by which it is connected to the antenna circuit is called "coupling." One method of coupling is shown by the diagram in Fig. 3. The inductance coil of the secondary circuit is simply placed close to the inductance coil of the antenna circuit. The magnetic effect of the latter coil gives rise to a current in the other coil. The condenser in the secondary circuit is varied until maximum current is produced. The amount of this current depends also on the position of the two coils with respect to each other.

The process of coupling may be considered as a sort of straining or filtering scheme to take in the wave

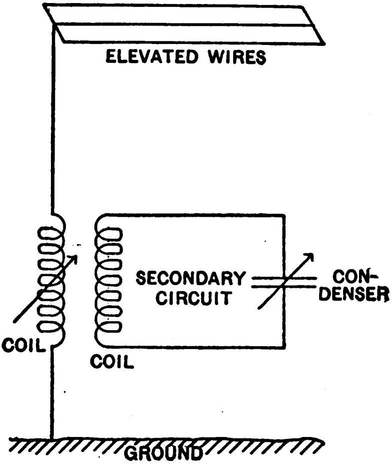


Fig. 3—Coupled circuits to improve tuning.

desired and exclude others. The antenna circuit filters out the wave desired to a certain extent, by the process of tuning. This is passed on to the secondary circuit which filters once again, thus refining or purifying the received wave still further.

The Detector.—Besides receiving the radio current in an antenna and adjusting the circuits so that the current is as great as possible, there yet remains something to be done before it becomes possible to translate the received radio current into a sound that can be heard in the telephone receiver. When one of the groups of alternations shown in Fig. 10, chap. 4 acts on the telephone receiver it causes no motion of the diaphragm because each variation of the current in one direction is immediately followed by the current in the opposite direction so that the resulting effect of the group of waves upon the telephone receiver diaphragm is no motion at all. It is therefore necessary, in order to convert the current into a sound, to use something else with the telephone receiver. This something else must be such as to make the current flow through the telephone receiver in only one direction. It must allow the electric current to flow through it in one direction and stop current which tries to flow through it in the opposite direction; that is, it must be some sort of electric valve. The effect of such an electric valve, may, perhaps be understood more clearly by taking a sheet of paper and placing it upon Fig. 10, chap

4, so as to block out the lower half of the waves shown. This leaves only the upper halves of the little groups of waves and this is exactly what the electric valve does. The thing which acts as an electric valve is called the detector. Using it, successive impulses of current flow through the telephone receiver and all of these tiny impulses in any one group add their effects together and produce a motion of the telephone diaphragm.

Crystal Detector.—The simplest detector is a piece of crystal with a fine copper wire in light contact with it. (There are variations from this, sometimes two crystals in contact are used). The crystal most commonly used is galena (lead sulphide). At the contact between the crystal and metal, current can flow in one direction but not in the other. When connected to a circuit, therefore, in which alternating current is flowing, it allows only the current impulses in one of the directions to flow through it. It thus has the electric valve action of which we have been speaking.

Electron Tube.—The most satisfactory and sensitive detector is the electron tube. This remarkable device, as will be shown, is not only useful as a detector but also as a high-frequency generator, as a modulator, and also as an amplifier by means of which the currents are more readily controlled and utilized. It is very satisfactory and stable in operation for all these various purposes. The basic principles of action of the electron tube are now discussed. For further study, the student is referred to "The Principles Underlying Radio Communication." Chapter 6. (See note, page 7, chap. 3).

The electron tube is a very simple device which looks more like an ordinary incandescent lamp bulb than anything else. While experimenting in the development of the incandescent lamp Edison made the discovery that an electric current could be made to flow in the empty space inside the bulb near the hot filament. If a metal plate is placed inside of an incandescent lamp bulb near the filament (Fig. 4) and if by means of a wire through the glass this metal plate is connected by wire through a battery and an indicating instrument to the filament, a current will flow as indicated by the instrument. A current is flowing in the wire and also flowing across the empty space between the filament and the plate. By much patient scientific research, scientists have found that this current taking place in the lamp consists of the flow of a stream of very small electric particles called electrons. These electrons are shot out into the surrounding space in all directions by the hot filament. The electrons may be said to fill the bulb like a vapor. They move at random in all directions unless there is an electric force to make them move in some particular direction. The battery connected in the circuit outside the bulb

supplies an electric force which acts between the filament and plate and makes the electrons move from the filament to the plate. If the battery is disconnected, there is no current, and as many electrons as strike the plate fall off again into the bulb. The current depends on the number and speed of the electrons. The battery is what gives them their speed in the direction from filament to plate. The battery

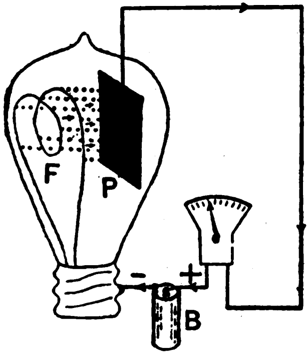


Fig. 4—Use of electron flow from hot filament (arrows show direction of electron flow, the reverse of the conventional direction of current).

performs much the same action as a steam pump would if the bulb were a room into and out of which steam pipes were connected. If the pump were disconnected, there would be no flow of steam, and when the pump is connected, steam is made to flow into and out of the room and through the pipe.

The point of all this is that the electron flow in the bulb has a sort of valve action. The electrons are shot out from the very hot filament and can be made to flow toward the plate by connecting a battery in the proper direction. If the connections of the battery are reversed, however, no current will flow because there is no such emission of electrons from the plate, which is cold; the electric force produced by the battery in this case has nothing to work on and can do nothing except prevent the flow of electrons out of the filament to the plate. It should be clearly understood before going further that the action of the electron tube thus depends upon the fact that an electric force can be applied in one direction which causes an electric current from the filament to the plate, but that if this electric force is reversed no current flows. The device gives exactly the rectifying action needed in order to make the received signals in radio produce sound in a telephone receiver. Suppose that the bulb shown in Fig. 4 is connected to a radio receiving circuit in place of the battery. Suppose also that the indicating instrument

is replaced by a telephone receiver. This is shown in Fig. 5. The pulses of current in the receiving circuit similar to those of Fig. 10, chap. 4, produce electric force inside the bulb between the filament and plate which alternates in direction just as the pulses of current do. On account of the rectifying action, current can flow through the bulb only in one direction, and consequently

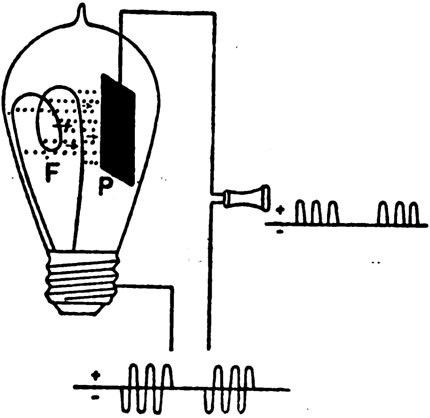


Fig. 5—Showing principle of detector action.

the pulses of electric force in one direction only are effective. As a result, pulses of current flow through the telephone receiver in groups, the pulses being all in one direction. This causes a note in the telephone receiver, as already explained.

The Purpose of the Grid.—An improvement in the original electron device was made by L. De Forest which very greatly extended its power and usefulness. As shown in Fig. 6, a grid of very fine wire is placed in the tube between the filament and the plate. The grid is placed closer to the filament than to the plate. The electrons which are emitted by the filament can move freely between the grid wires. If by means of a battery or something else an electric force is established between the filament and the grid, this electric force causes electrons to move away from the filament toward the plate, and since the grid is placed much closer to the filament, the electric force makes the electrons move much faster than would the same electric force between the filament and plate. Very few of the electrons are taken by the grid, and a very small current thus goes through the wire connected to the grid. Thus a very small current to the grid controls the flow of a much larger current to the plate. Hence a larger current can be taken out of the tube

than is put into it. A small electric force acts between grid and filament, causing a large electron flow from filament to plate. There results a relatively large flow of current in the apparatus connected outside the tube between the plate and filament.

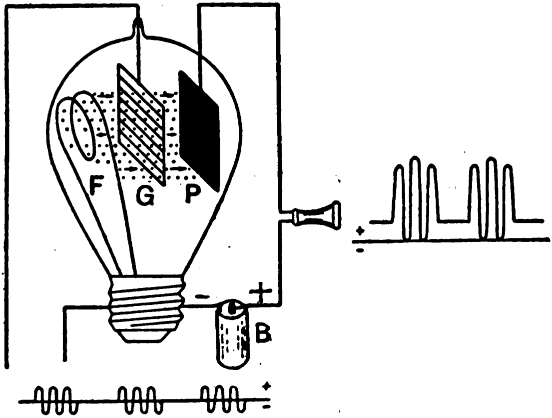


Fig. 6—Three-electrode tube as detector.

This device is commonly called an electron tube. (It is also known by many other names, as vacuum tube, audion, triode, and radiotron.) It magnifies or amplifies electric currents. It accomplishes the control of a large amount of power by a small power. This is just the same thing that a gun does—pressing the trigger several times in a repeating pistol is like the action of the tube with successive pulses of electric force. The grid corresponds to the trigger, and the plate to the gun barrel.

Electron tubes which are used as detector tubes ordinarily have a slight amount of gas remaining inside. These are more sensitive than the highly evacuated tubes used as amplifier tubes, but they require more careful adjustment of the current which lights the filament and of the voltage of the battery connected to the plate circuit. On account of the fact that the adjustments are not so critical when amplifier tubes are used, many operators prefer to use them as detector tubes.

Amplifier.—On account of the control of the plate current by a smaller grid current, the electron tube makes possible some very wonderful things.

It is perfectly possible and quite easy to take the magnified output from an electron tube and pass it into a second electron tube, using that to make a still further amplification of the current. Using one tube after another in this way, we obtain what is called an

Antenna: Converts radio wave into an alternating current of high frequency.

Inductance Coil: Forms, together with the antenna, a circuit which can be tuned to respond to the incoming radio wave. In this set it alone constitutes the "tuner".

Crystal Detector: Converts the alternating current in the antenna into a pulsating unidirectional current.

Telephone Receivers: Convert the pulsating unidirectional current into sound.

The functions of the parts of the two-circuit electron tube set as shown in Fig. 12, Chap. 2 may be summarized as follows:

Antenna: Converts radio wave into an alternating current of high frequency.

Primary Inductance Coil: Forms, together with the antenna, a circuit which can be tuned approximately to respond to the incoming radio wave. In this set it is the primary coil of the "coupler."

Series Condenser: Shortens the wave length to which the antenna responds. It also gives fine adjustment of the tuning of antenna circuit.

Secondary Circuit: Provides means of tuning more sharply to the desired wave than can be done by tuning in the antenna alone. It consists of the secondary inductance coil and the secondary condenser.

Secondary Inductance Coil: Couples the secondary circuit to the antenna circuit. It provides rough adjustment of tuning of secondary circuit.

Secondary Condenser: Provides fine adjustment of tuning of secondary circuit.

Electron Tube: Converts the alternating current in the secondary circuit into a pulsating unidirectional current and amplifies it.

Filament Battery (A): Supplies current to heat the filament of the electron tube.

Filament Battery Rheostat: Regulates current through the filament of the electron tube.

Plate Battery (B): Supplies current through the tube between plate and filament.

Telephone Receivers: Converts the pulsating unidirectional current from the electron tube into sound.

The functions of the several parts of the regenerative set shown in Fig. 13, Chap. 2 may be summarized as follows: All parts are the same as in the two-circuit electron tube set above except the following:

Tickler Coil: Feeds the effect of the current in the plate circuit back into the grid circuit so that the current is re-amplified.

Grid Condenser and Leak: Adjust voltage on the grid to a value giving sensitive action of electron tube as a detector.

Potentiometer Resistance: Provides fine adjustment of plate voltage.

Telephone Condenser: Provides path for radio-frequency current that is easier than through the telephone receivers.

The functions of the parts of the amplifier shown connected to a crystal detector set in Fig. 15, Chap. 2, and to an electron tube set in Fig. 16, Chap. 2, as far as not already covered above, are as follows:

Electron Tubes: Convert the small voltage and power applied to the grid into larger voltage and power in the plate circuit.

Amplifier Transformers: Convert the small voltage applied to the input side into a larger voltage on the output side.

Generators of Radio-Frequency Current.—Turning now to radio transmitting apparatus, the principal apparatus which is required is a generator of alternating current of radio frequency. There are numerous kinds of generators, but the kind used in radio telephony makes use of powerful electron tubes. These tubes have filament, grid, and plate, the same as the electron tubes used in receiving sets, but are larger and more powerful. (See Frontispiece).

The way in which electron tubes are used to generate current is a mere extension of their use in amplifiers. If, in Figure 8, the coils L_1 and L_2 are placed close together, the effect of L_2 on L_1, can become so great that the current continues to flow even if no signals are coming into the antenna to which the input circuit CL_1, is connected. The alternating current thus produced will have the frequency to which the circuit CL_1, is tuned. What happens might be expressed by saying that an amplifier can be made so powerful that no input current at all is required. This does not mean that it is a perpetual motion machine, because the power to operate it must be supplied by the battery that is connected in the plate circuit of the tubes. It does mean, however, that the electron tube can be used to generate alternating currents as well as to receive and to amplify them.

Apparatus for Transmitting Radio Telegraph Signals. The apparatus for transmitting radio telegraphy and telephony differ mainly in the arrangement by which the continuous current produced by the generating circuits is modulated or changed in strength to follow the dots and dashes of the telegraph code or the variations of the voice. Radio telegraph transmitting sets are the simpler. Means are provided to modulate the radio-frequency current at an unvarying audible

frequency. To signal it is only necessary to stop and start the current suddenly by means of an ordinary telegraph key which opens and closes the circuit. The inductance coils and condensers are of somewhat different design than the coils and condensers used in receiving sets. In transmitting sets the various parts of the circuit must carry considerably larger currents. The filaments of the electron tubes are lighted from storage batteries, as in receiving sets, but the "B" battery (battery in plate circuit) is replaced by a dynamo which will supply

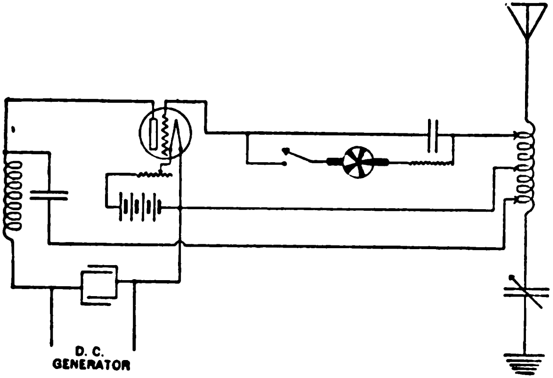


Fig. 9—Circuits of radio-telegraph transmitting set using chopper for securing modulated waves.

more power than is economically obtained from batteries. The voltage of this dynamo may be between 300 and 2000 volts. The power which it delivers depends upon

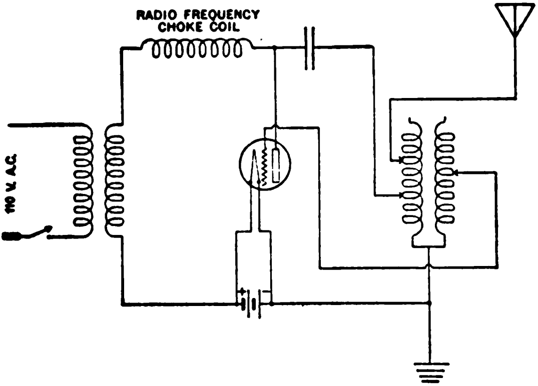
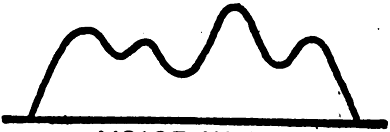


Fig. 10—Circuits of radio-telegraph transmitting set using alternating current for plate supply and modulation.

the type and number of electron tubes used in the transmitting set. The power of the set may be increased by using a larger electron tube or by connecting additional tubes to the circuit. In the latter case the grids of all of the tubes are connected together and the plates of all of the tubes are likewise connected together. The filaments are all heated by current from the same storage battery.

One type of radio-telegraph transmitting circuit is that shown in Fig. 9. This shows one of various methods of connecting the key for use in signalling. It also shows how to connect a chopper (motor-driven interrupter) in order to modulate or break up the waves into groups at an audible frequency. Modulation of the waves may also be secured by using an alternating voltage to supply power to the plate circuit of the transmitting tubes. During the half of each cycle of this voltage, when it makes the plate negative, no current flows. It thus serves the purpose of a chopper. A circuit diagram for such a set is shown in Fig. 10.



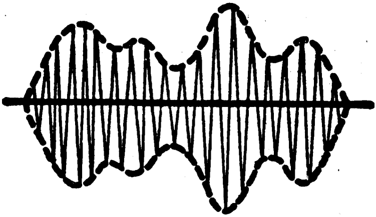


Fig. 11—Voice-modulated radio wave.

Modulation in Radio Telephony.—The electron tube is the device used to modulate the radio-frequency current in radio telephone transmitting apparatus. The general idea of modulation was explained in Chap. 4. The human voice produces sound waves which cause air vibrations of an irregular character. Such a wave may be roughly illustrated as in Fig. 11. The variations in the voice wave are much slower than the alternations of current used in radio. It is possible to make a radio wave carry a voice wave, and when this voice-modu-

lated wave is received it can be passed through a detector and telephone receiver and the voice heard just as radio telegraph signals are heard. The way in which the voice wave is super-imposed upon the radio wave is illustrated in Fig. 11. The alternations of the radio wave are shown by the full lines, and the dotted boundary lines show that the intensity of the wave has been made to vary in accordance with the sound wave produced by the voice. This wave can be received in exactly the same way as any wave in radio-telegraphy—no special apparatus is required for receiving radio telephony. The voice at the transmitting station is heard very clearly. It can be made as loud as desired at the receiving station by the use of amplifiers.

The radio wave is really modulated or molded just as a phonograph record is molded by a sound wave. The means by which this modulation is accomplished is the electron tube. If in Fig. 6 the telephone receiver is replaced by any kind of generator of radio-frequency current, then if a person speaks into a telephone transmitter connected between the grid and filament of the tube, the variations caused by the sound of the person's voice cause the intensity of the radio-frequency current in the plate circuit to vary correspondingly with the voice sound wave. The radio-frequency current is thus not of constant amplitude but varies in amplitude in accordance with the voice. Thus a modulated radio wave as in Fig. 11 is produced.

Radio Telephone Transmitting Apparatus.—The circuit of a radio telephone transmitting set is similar to that of a radio telegraph transmitting set except for

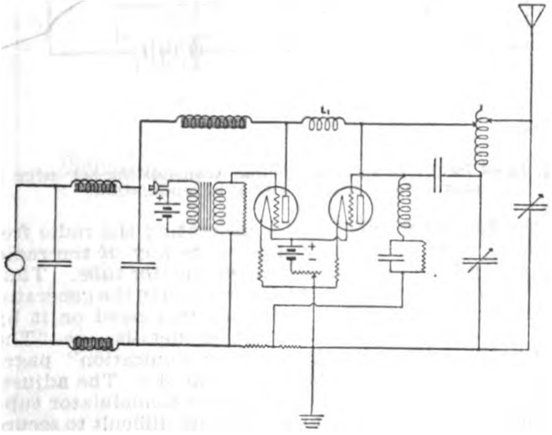


Fig. 12—Circuits of radio-telephone transmitting set using one generator tube and one modulator tube.

the modulating device. A diagram of a complete set is shown in Fig. 12. Here the microphone, into which the speaker talks, is connected through a suitable transformer to the grid and filament terminals of an electron tube. This tube on account of this use is called the modulator tube. The plate current from this tube varies according to the sound-wave variations of the voice. The plate current of the generator tube, which is to the right of the modulator tube, has variations corresponding to those of the modulator tube because there is a choke coil in the lead from the generator (at the left) which keeps the sum of the direct current supplied to the plate circuits of the two tubes constant. The arrangements of coils and condensers to the right

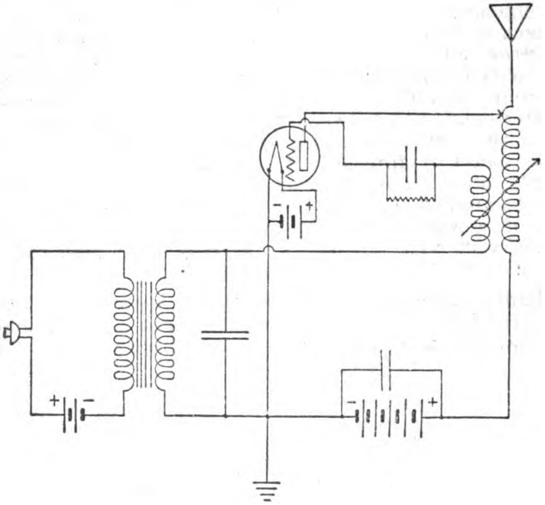


Fig. 13—Circuits of radio-telephone transmitting set using a single electron tube with grid modulation.

of the generator tube are for generating the radio frequency. The choke coil L_1 prevents any of the radio frequency from getting into the modulator tube. Thus the radio-frequency current is produced in the generator tube and has the voice variations impressed on it by the modulator tube. For further details, see "The Principles Underlying Radio Communication" pages 521 and 527 (see note, page 7, Chap. 3.) The adjustments of the circuits associated with a modulator tube are usually very critical and it is quite difficult to secure accurate production of current which varies in exactly the same way as the sound waves of the voice.

A somewhat simpler circuit arrangement, in which a single tube serves as both generator and as modulator, is that shown in Fig. 13. It is even more critical in adjustment but is sometimes used where a low-power transmitting set with a simple circuit arrangement is desired.

Continuous-Wave Radio Telegraphy.—While considerable stress has been laid in all these explanations on the process known as modulation, the reader should know that there is a system of radio telegraphy in which there is no modulation. This should be kept apart, however, in thinking on radio, as it is done by distinctly different processes. There being no modulation, the wave is simply an unvaried continuous wave of radio-frequency. A circuit diagram of a continuous-wave transmitting station is given in Fig. 14. The bare essentials of this diagram are given in Fig. 8. For

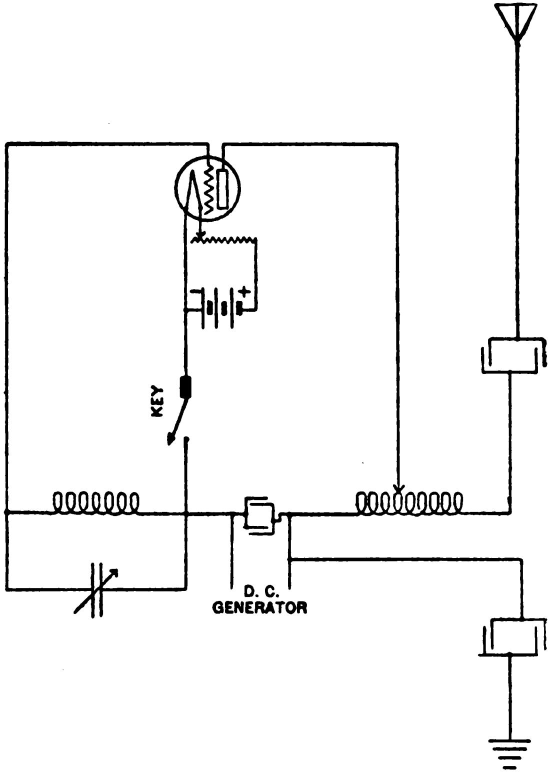


Fig. 14—Circuits of continuous-wave radio telegraph transmitting set.

further explanation of the features of circuits like Fig. 14 see "The Principles Underlying Radio Communication," pages 491 to 498 (see note, page 7, chap. 3).

A "continuous wave" would not be heard in the ordinary receiving set, because as already explained the frequency of radio waves is so high that the human ear does not react to a sound of such high frequency. These continuous waves are received by an ingenious scheme. In the ordinary regenerative receiving set, the coupling of the "feedback" from the plate to grid is increased until the circuit begins to generate ("oscillate"), as explained on page 12 under "Generators of Radio-Frequency Current." The condenser is adjusted until the circuit is tuned to a frequency just a little different from that of the received continuous-wave current. There are thus present two high-frequency currents of slightly different frequency, the received current and the generated current. Beats are produced between the two and these beats are heard in the telephone receivers. Thus if the continuous wave frequency is 200,000 and the generated current frequency is 201,000 a beat note of a frequency of 1000 is produced, and this is readily heard.

The signals from a nearby continuous-wave radio telegraph transmitting station are heard in the ordinary receiving set (which is not oscillating) as a series of clicks, a click occurring at the beginning and end of each dot and each dash of the code signals. If the receiving set is, however, so adjusted as to be generating ("oscillating") the signals from a continuous-wave radio telegraph station are heard as long and short whistling sounds forming the dashes and dots. Sometimes signals are heard which cause the series of clicks referred to above, but also have a low-pitched, humming sound distinguishable as forming the telegraph code signals. Such signals are produced from a transmitting set which uses alternating current supply for the plate circuit of the transmitting tube.

Spark Radio Telegraphy.—While the electron-tube transmitting sets for both radio telegraphy and radio telephony are being installed generally where new stations are being erected, there are a large number of old stations in operation which employ entirely different apparatus. Many of the commercial stations for radio telegraphy between ships and shore and many amateur radio transmitting stations are of old types. These older transmitting sets are called spark sets because the high-frequency alternating current in the antenna is produced by the discharge of a condenser across a spark gap. The waves sent out from a spark transmitting station are able to create much more interference than the waves sent out from a well-

designed electron-tube transmitting station. A diagram showing the circuit used by a spark transmitting set is that given in Fig. 15. An alternating-current generator is connected to the primary of a transformer whose secondary circuit supplies an electric charge to a condenser. This condenser discharges through the inductance coil P and the spark gap. This produces a corresponding current in the inductance coil S of the antenna circuit. There results a series of trains of waves which are called damped waves.

For a further study of the principles of radio transmitting and receiving apparatus, the reader is referred to "The Principles Underlying Radio Communication," Chapters 5 and 6. (See note, page 7, Chap. 3).

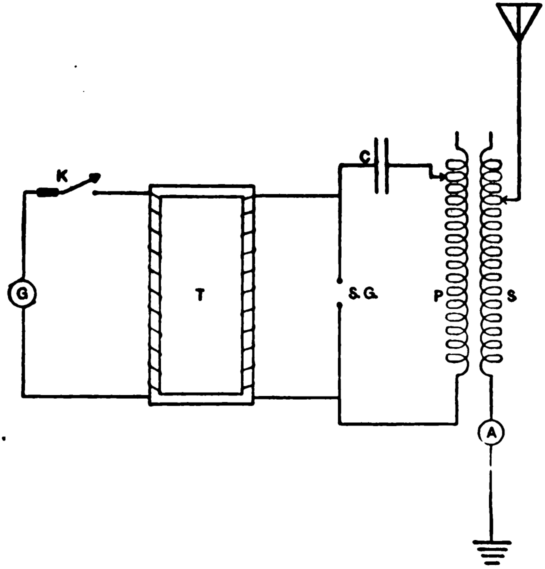
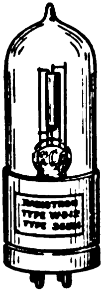


Fig. 15—Circuits of spark type of radio telegraph transmitter.

A—Ammeter measuring radiated energy.
C—Condenser.
G—Alternating-current generator.
K—Operating key.
P—Primary of inductance coil.
S—Secondary of inductance coil.
S. G.—Spark gap.
T—Transformer.

TUBE CHARACTERISTICS

Westinghouse WD-11 and WD-12 Radiotrons



Radiotrons WD-11 and WD-12 are designed to operate either as detectors or amplifiers. They are identical except for the base, the WD-11 having a special type, while WD-12 is equipped with the standard base.

The filament takes a normal current of 0.25 ampere with an applied voltage of 1.1. These limits enable the tube to be operated on one standard No. 6 dry cell. The filament consists of a very thin strip of platinum-iridium alloy drawn as a wire and rolled flat. This is coated with a mixture of metallic oxides.

Successful operation of the tube requires constancy of voltage across the filament. As energy is drawn from dry cells, the voltage gradually drops, and this decrease in voltage must be compensated for by adjusting the rheostat. When the cell voltage drops to 1.1 volts, successful operation can no longer be obtained, as sufficient electron emission will not be secured with less current in the filament than can be obtained with a terminal voltage of 1.1 volts.

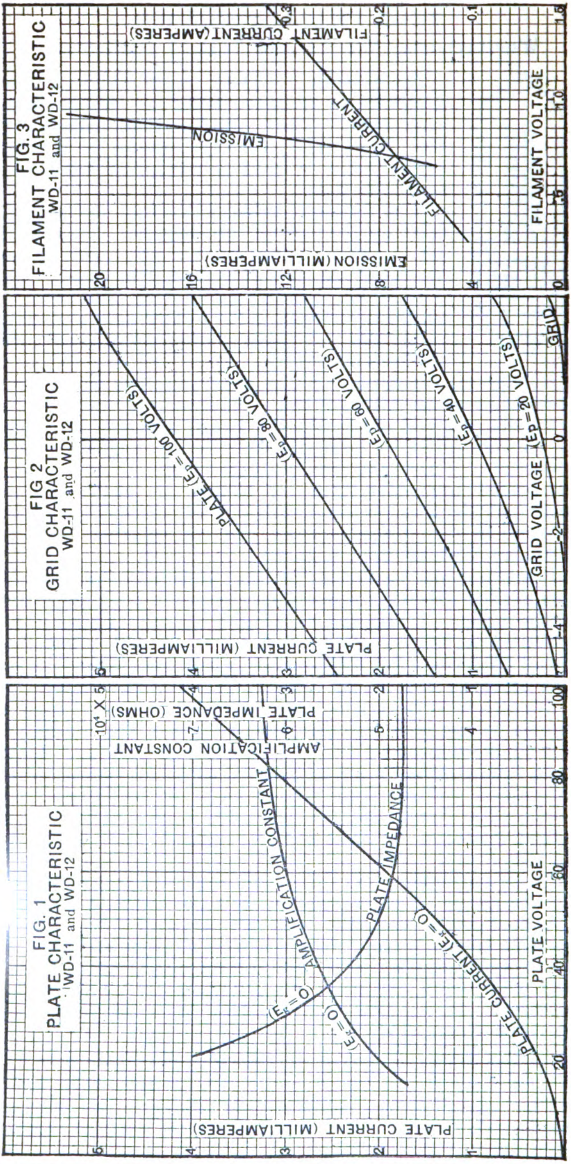
Considerable variation of filament temperature is permissible without appreciable change in the operation of the tube. While the rated current of 0.25 ampere produces a bright, cherry-red color, it will often be found that the tube will operate when the filament is so dim as to be practically invisible even in the dark.

When a WD tube is used as a detector, the grid return should be connected to the positive end of the filament. A grid condenser of 0.00025 microfarad and grid leak from 2 megohms up are necessary with this connection. Any plate voltage from about 16 to 50 volts may be used. The tendency to oscillate is greater at the higher voltages, so that a value about 22.5 volts is usually found best.

As an amplifier, WD tubes will operate through quite a wide range of plate voltage, but best results will be obtained with voltages between 45 and 120. It is possible to use higher plate voltages than this if care is taken to keep the grid sufficiently negative. When only 22.5 volts are used no separate "C" battery is required. In general, the following negative grid bias voltages are suitable:

40 volts plate . . 1.0–1.5	80 volts plate . . 3.0–4.5
60 volts plate . . 1.5–3.0	100 volts plate . . 4.5–6.0

The amplification constant of these tubes varies considerably over the range of plate voltage, from about 5 to 6.25.



CHARACTERISTIC CURVES

TUBE CHARACTERISTICS

General Electric Co. UV-200 Radiotron

The UV-200 Radiotron was designed primarily as a detector, and was to replace the numerous sensitive, but unreliable, gas or air-content tubes which have been on the market from time to time.

When used as a detector, the filament of the UV-200 should be operated at constant voltage, although a voltmeter is not necessary, because good detector action takes place only approximately at the correct value. Close variation of the plate potential is necessary for satisfactory performance. Since the tube was designed for a plate voltage of 18 to 23.5, a 22-volt block battery may be used to advantage. In some cases plate voltage steps of 1.5 volts (or the taps from consecutive dry cells) are sufficient, the adjustment being secured with the filament rheostat if it is continuously variable. A grid leak of approximately 0.5 megohm is recommended with a grid condenser of approximately 0.00025 μf., although results may be obtained without a grid leak and condenser. The grid return should always be to the negative filament lead.

The UV-200 does not have an amplification constant in the usual sense; that is, a variation of a fraction of a volt on the grid and the plate may cause a variation of amplification constant between 1 and 6. In a similar way the impedance and mutual conductance are extremely critical. This is one of the characteristics of a gas-content detector tube and is the very reason why, under certain conditions, extreme sensitivity is obtained. However, with 20 volts on the plate, the impedance varies widely, but averages 9,000 ohms.

These tubes when operated with —1.5 volts on the grid and 25 to 30 volts on the plate act as amplifiers. The plate voltage is not critical within 2 or 3 volts. The amplification with most tubes increases rapidly with plate voltage until a point is reached where there is a distinct maximum, this being at about 27 volts. Above this point violent ionization occurs and the amplification decreases to a very low value.

With reference to the plate characteristic curve shown in Fig. 1, it must be remembered that this curve cannot be taken to apply to any one particular tube. The variation among tubes is so great that no one curve can be considered an average curve, and any values given would not be particularly valuable to the user of a tube. To obtain an idea of the general plate characteristic, however, several tubes have been picked out at random and the values averaged. This curve is not to be considered as the official curve of the UV-200. It is simply the result of a test on a tube which might be termed an average tube.

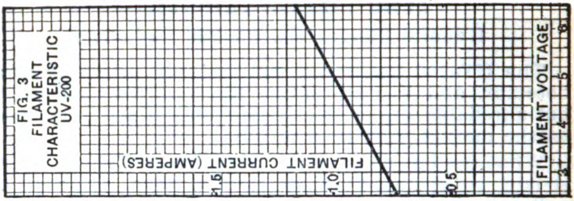


FIG. 3
FILAMENT
CHARACTERISTIC
UV-200
FILAMENT CURRENT (AMPERES)
1.5
1.0
0.5
FILAMENT VOLTAGE
3
4
5
6

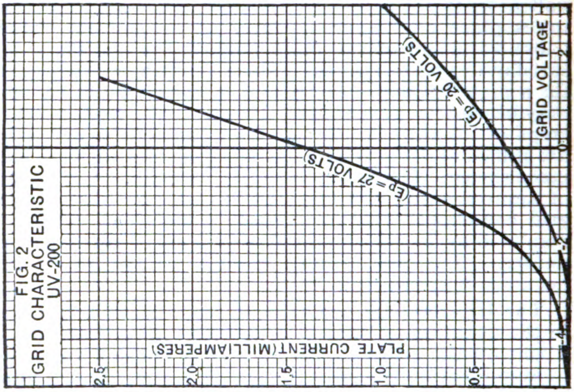


FIG. 2
GRID CHARACTERISTIC
UV-200
PLATE CURRENT (MILLIAMPERES)
2.5
2.0
1.5
1.0
0.5
(E_p = 20 VOLTS)
(E_p = 27 VOLTS)
GRID VOLTAGE
4
2
0
2

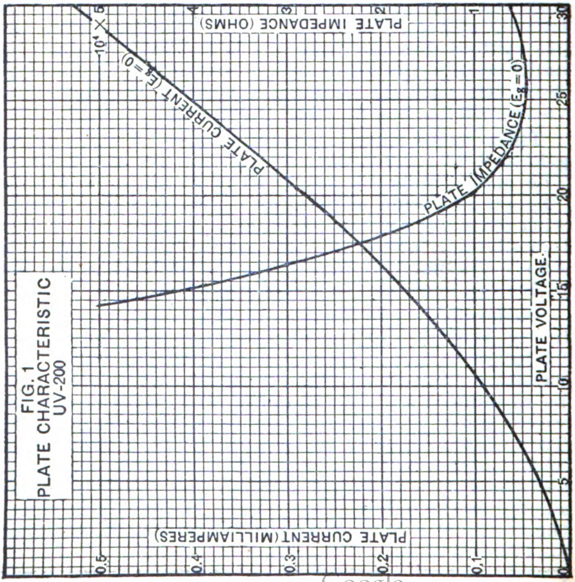


FIG. 1
PLATE CHARACTERISTIC
UV-200
PLATE IMPEDANCE (OHMS)
$10^4 \times 5$
4
3
2
1
PLATE CURRENT (E_g = 0)
PLATE IMPEDANCE (E_g = 0)
PLATE CURRENT (MILLIAMPERES)
0.5
0.4
0.3
0.2
0.1
PLATE VOLTAGE
0
5
10
15
20
25
30

CHARACTERISTICS OF RECEIVING TUBES

A properly operated tube gives most satisfaction

The following table gives the characteristics of the vacuum tubes in general use for receiving. Considerable variation is allowable for the values of grid voltage, condenser and leak, but the values given are recommended for good results.

Although this table gives a fair idea of the value of the most important constants, it must be used with certain reservations. As regards the life of the tubes, some manufacturers prefer not to publish information concerning this subject. This is not due to the fact that they wish to hide from the public any deficiencies in this respect, but because, as in the case of incandescent lamps, the conditions of operation vary so widely that many figures given would have no meaning whatsoever to the user. In the manufacture of tubes, standard life conditions are assumed for each type of tube and extensive tests carried on in this respect. These chosen conditions are supposed to represent average conditions, but in the laboratory, elaborate apparatus is used to maintain these conditions absolutely constant, day and night, which, of course, cannot be done by the user. In the case of filaments of all vacuum tubes, a small variation in voltage or current means a very much larger variation in life. For instance, approximately a 5% variation in voltage will halve or double the life of the filament.

For similar reasons, values of the grid impedance have been omitted from the table. This is an extremely variable quantity, the variation from tube to tube being so tremendous that an average value is worth very little. Fortunately, the performance of tubes in practically all present-day circuits is quite independent of this constant so long as it is above a certain value.

In the case of the UV-200 and C-300 tubes, they do not have an amplification factor in the usual sense; that is, a variation of a fraction of a volt on the grid and the plate may cause a variation of amplification constant between 1 and 6. In a similar way, the impedance and mutual conductance are extremely critical. This is one of the characteristics of a gas content detector tube, and is the very reason why, under certain conditions, extreme sensitivity is obtained.

Most efficient operation of a vacuum tube outfit depends on the values of the grid, plate and filament voltages. Moreover, whether the tube acts as a de-

tector, amplifier, or oscillator, depends likewise upon these quantities. Any tube may act in any of these three capacities. This table outlines the characteristics of the various receiving tubes, and supersedes the table previously given in the June Radiofax. All values in the tables were furnished by the manufacturers.

Table of Characteristics

FILAMENT				PLATE			GRID			Amplification factor	Mutal conductance, Micromhos
Volts	Amps.	Watts	Emission Amps.	Volts +	Amp.	Ohms	Volts (—)	Condenser μf	Leak Megohms		
UV-199* C-299 Thoriated Tungsten Filament											
3.0	0.060	0.18	.008	40	.0009	19,600	0.5–1.0	.00025	2–9	6.20	315
....	....	.....	....	60	.0017	18,000	1.0–3.0	......	......	6.20	350
				80	.0021	16,000	3.0–4.5	......	......	6.25	400
				100	.0026	14,000	4.5–6.0	......	......	6.30	440
UV-200 C-300 Tungsten Filament											
5.0	1.0	5.0	....	20	.00033	10,000	....	.005	0.5	Variable	Variable
				27	.00048	20,000	1.5	......	......		
UV-201 C-301 Tungsten Filament											
5.0	1.0	5.0	....	20	.000[illegible]	[illegible]5,000	....	.005	1	5.5	157
				40	.000[illegible]	[illegible]2,000	1–2	......	......	6.0	273
				60	.0020	16,600	2–2.5	......	......	6.1	368
				80	.0025	15,000	2.5–3	......	......	6.15	410
				100	.0033	14,000	3–4	......	......	6.2	443
UV-201-A C-301-A Thoriated Tungsten Filament											
5.0	0.25	1.25	.045	40	.0007	15,400	0.5–1.0	.00025	2–9	6.50	345
				60	.0013	11,100	1.0–3.0	......	......	6.55	425
				80	.0021	9,600	3.0–4.5	......	......	6.60	535
				100	.0028	8,800	4.5–6.0	......	......	6.60	630
WD-11* WD-12 Platinum-Iridium Coated Filament											
1.1	0.25	0.27	....	20	.0003	30,000	....	.00025	2–10	5.7	190
				40	.0012	17,500	....	......	......	5.2	290
				60	.0020	13,700	0.5–1.0	......	......	5.8	420
				80	.0030	13,400	1.0–3.0	......	......	6.1	470
				100	.0040	13,000	3–4.5	......	......	6.2	480
DV-2 Thoriated Tungsten Filiment											
5.0	0.26	1.30	0.050	25	.001	20,000	0	.00025		6.75	350
				50	.0022	13,500	1			7.05	570
				70	.0042	10,000	1		1–5	7.20	720
				90	.0060	9,000	2			7.25	820
				120	.0080	9,000	4			7.30	920
DV–3 Thoriated Tungsten Filament											
3.0	0.07	0.21	.009	20	.001	35,000	0	.00025	2–6	6.75	240
				45	.0017	18,500	1			7.20	370
				70	.0027	15,500	1			7.30	470
				95	.0034	15,300	2.5			7.40	500

*Special base. All other tubes in this list fit the standard base.

THE SERIES CONDENSER

Many of our readers seem to have considerable difficulty in understanding the use of a series condenser, and in determining the proper size to use, judging from some of the letters we receive from them from time to time. The following chart will help to relieve this trouble, and at the same time will afford those who do understand the matter a means of arriving at the proper size condenser to use under various conditions and sizes of antenna.

When using condensers in parallel, the total capacity is merely the sum of the several capacities. When using them in series, their reciprocals add. In mathematical symbols, for parallel capacities

$$C = C_1 + C_2 + C_3 + \ldots, \text{etc.},$$

and for series capacities

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots, \text{etc.}$$

In the latter equation, when we have only two condensers to consider, as for instance, the antenna capacity and the series condenser, we have $1/C = 1/C_a + 1/C_s$. This may be written

$$C = \frac{C_a C_s}{C_a + C_s}$$

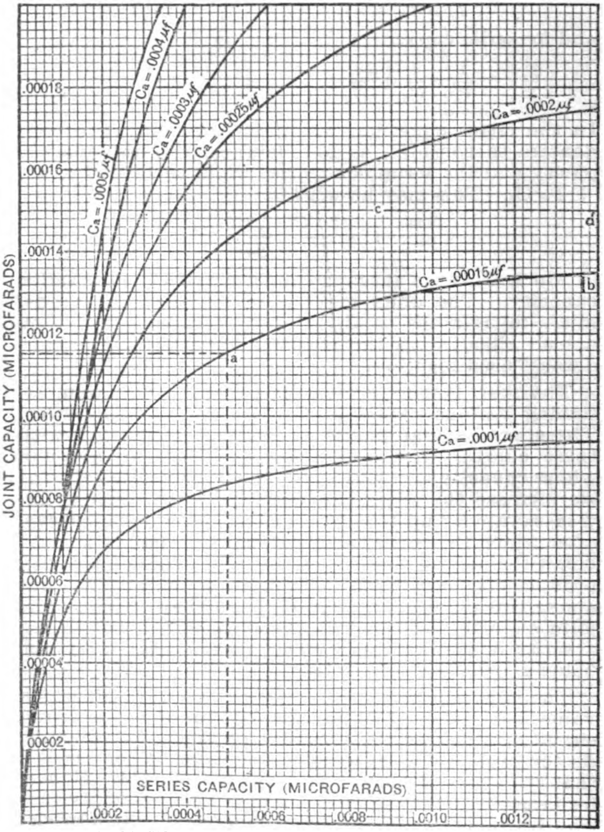
in which C_a is the antenna capacity and C_s is the series capacity. The units may be in microfarads, farads, micro-microfarads, or anything we please, just so they are all alike. C is the resulting capacity of the condensers used together.

The chart is merely the solution of this equation, assigning various values to C_a for each of the curves. There are several points of interest connected with these curves. Let us suppose we have an antenna whose capacity is 0.00015 μf. It will be noticed that as we increase the series capacity, the joint capacity increases rapidly up to the point marked *a* on the curve, after which the curve rises very slowly; that is to say, below the point *a* changes in the value of series capacity produce considerable changes in the joint capacity, but above this point changes in C_s have little effect on the joint capacity. So in this case it does not pay to use a series condenser larger than that indicated by the point *a*, or 0.0005 μf.

The joint capacity for this case is 0.000115 μf, which value is to be used in all calculations of the antenna circuit, instead of the capacity of the antenna alone. As the capacity of the antenna increases, it will be seen that the knees of the curves move to the right. Hence, for larger antennas we may use larger series condensers. The introduction of the series condenser into the cir-

cuit reduces the total capacity of the system, and as it is reduced, the total capacity is reduced further. The joint capacity of two condensers in series can never be as great as the smaller capacity, if either capacity is less than unity, but as the larger capacity is increased, the joint capacity approaches the value of the smaller. Thus, in the case of an antenna capacity of 0.00015 μf, the curve *a b* gradually approaches the line *c d*, which intersects the vertical scale at the same value, 0.00015 μf.

Naturally, when the capacity of the antenna system is decreased, the wavelength or resonant frequency of the circuit is decreased. Hence a series condenser is often called a "short-wave" condenser.



THE USE OF THE "C" BATTERY

Why it is used and what it does

The advantage of the "C" battery has been known for a long time; it was first used in telephone repeaters to make possible the attainment of great amplification through the use of high plate voltages, without the usual attendant distortion. In radio it is used for the same purpose, but this is not the only reason.

Effect of Grid Voltage on the Characteristic

Figure 1 shows the grid characteristic curves of the UV-201A Radiotron. Two curves are shown, one for a plate voltage of 100 and another for a plate voltage of 40. The effect of increasing the plate voltage is seen to move the curve to the left and at the same time upward. With zero volts on the grid, for instance, and 40 volts on the plate, we obtain a plate current of 1 milliampere. If we now increase the plate voltage to 100 volts, leaving the grid voltage zero, the plate current jumps up to 7.4 milliamperes. This is a very great increase in the plate current and in many cases may be desirable. But let us see further what happens.

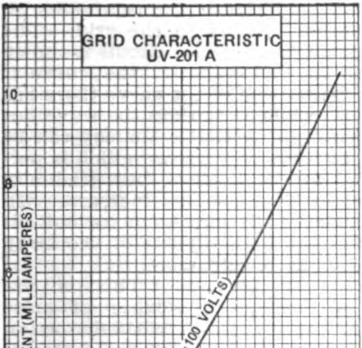


Fig. 1

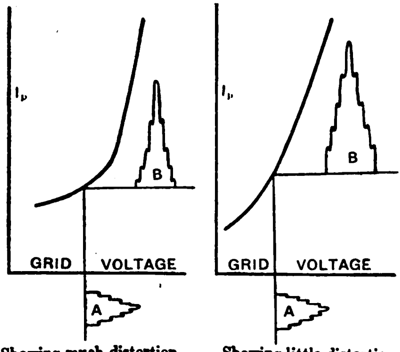
Notice that in the first case, where we were using the lower curve in the figure, with 40 volts on the plate, that we were working on the bend of the curve near the bottom. This is one of the conditions required for operation of the tube as a detector. When we increased the plate voltage, thus making the tube operate on the 100-volt curve in the figure, we made the tube operate on the straight portion of the curve. This is one of the conditions required for operation of the tube as an amplifier. To come down to the bend in the 100 volts curve it will be necessary for us to have a voltage on the grid of about —8 volts. But detectors are never operated with such high voltages on the plates. High voltages are used for amplification. In the present case a voltage of —4 to —4.5 volts on the

grid is a good value for amplification. Of course it is noticed that as the grid bias is increased, the plate current decreases. This is not what we desire, but in radio we often must be content with sacrificing amplification for quality of tone and stability of operation.

Causes of Distortion

If we wish to amplify a sound wave it is evident that every one of the frequencies that exist in it must be amplified in the same proportion. This is not all that is required: every amplitude must be amplified in the same proportion likewise, otherwise sounds which are soft may be amplified, say, 4 times, and sounds which are loud may be amplified, say, 6 times. The ear hearing these sounds will then give more importance to some sounds than they deserve and insufficient importance to those which deserve more.

The reason for this can be seen in Figure 2. The tube is being operated on the bend of the curve, so that when there are equal increases and decreases of signal voltage applied to the grid, the increases of plate current are greater than the decreases. This is on account of the slope of the curve; the sharper the bend is, the worse is this condition of affairs. In Figure 2, A represents an incoming signal oscillation applied to the grid. The wave-shape of the current in the plate circuit is shown at B. The distortion in the shape of the curve is very noticeable; near the bottom of the curve there has been little amplification, while at the top the wave has been stretched considerably. A visible analogy can be obtained by standing in front of a mirror which is perfectly flat and vertical at the bottom, but gradually curves away as the height from the floor increases. In this case the lower parts of the legs seem to look all right, but we find that the higher parts of the body seem to be stretched out more and more.



Showing much distortion. Showing little distortion.

Fig. 2

This is the cause of most of the distortion in radio receiving circuits. Most of the distortion lies in the detector, since we generally operate a detector at the bend of the characteristic curve. The distortion in amplifiers, however, is very much less, and in many cases

is hardly noticeable, since we then work the tube on the straight portion of the curve. Here the increases and decreases are equal and the reproduction faithful.

Although amplitude distortion is the most important form of distortion that occurs in vacuum tubes, considerable distortion also results in the introduction of harmonics which were not present in the original wave, due to the curvature of the characteristic, even on its straightest portions. If the tube is properly handled, however, it is possible to eliminate distortion to such a degree that even the experienced ear cannot detect it.

There are other causes of distortion. Distortion will result if the tube is overworked. Distortion also results in regenerative circuits when tuned too near the critical point (i. e., the point of oscillation).

Reducing the Distortion

By pointing out the causes of distortion in tubes we are able to understand more fully what means are to be employed in eliminating it. The "C" battery plays an important part in this. Thus, referring to Figure 1, if we wish to use the UV-201A as an amplifier, using 100 volts on the plate, it will be necessary to use about 4 volts negative on the grid, so that we will be working on the straight portion of the curve. The question may arise as to why we do not use the tube without a "C" battery in this case, for, with zero grid volts we are still working on the straight portion. We must not forget the oscillating signal voltages that are impressed on the grid. These become positive part of the time, and if there is not sufficient negative bias present, it is likely that the net charge on the grid will sometimes be positive. When the grid is positive we have another cause of distortion, for this means a flow of electrons from the filament to the grid; in other words, the grid robs the plate of some of the electrons that should go to it. As a result, the plate current is diminished slightly. Moreover, the flow of current causes the grid voltage itself to drop, so that the full effect of the signal voltage is not felt by the tube. The remedy for this trouble, therefore, is to use a grid voltage higher than any positive value that the signal voltage may assume. This voltage is furnished by the "C" battery.

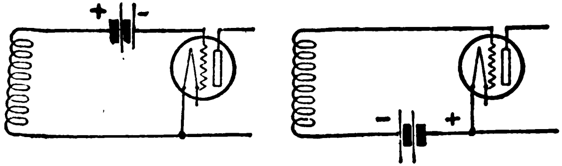
Proper Values of "C" Voltage

The values of negative grid voltage to use are subject to wide variations, but there are several points worth mentioning which go toward determining the best value to use for any tube. By following the reasoning at the beginning of this article an approximate value of bias voltage may be arrived at; the maximum value that may be used is determined by the circuit conditions existing in the receiver. It is

well known that when there is considerable inductance in the plate circuit there is a tendency for the system to oscillate. The reason for this is that the presence of the inductance lowers the effective resistance of the grid circuit. If the amount of inductance is so great that the grid circuit resistance is reduced to zero, or even becomes negative in value, the grid circuit, instead of *absorbing* power, will *furnish* power to the system. Up to the critical point where the resistance is zero we have regeneration; beyond that point, when the resistance is negative, we have oscillation.

The important point here is that when there is considerable inductance in the plate circuit, an excessive negative grid bias will cause the circuits to oscillate. Let us study the reason for this. The resistance of the grid circuit is measured by the voltage between the filament and grid divided by the current flowing in the grid circuit; that is, the resistance of the grid circuit is the reciprocal of the slope of the grid voltage-grid current characteristic curve. Evidently the more negative the grid becomes, the smaller is the slope of the curve. If the slope is less, the resistance, which is the reciprocal of the slope, will be greater.

There are several things contributing to prevent the tube from oscillating, among which is the current from the filament to the grid. In actual operation there is always a small grid current flowing, even when the grid is negative with respect to the filament. This grid current represents an absorption of power in the grid circuit, so that the grid current and the plate inductance have effects which are opposed to each other.



Methods of obtaining grid bias

By making the grid more negative, the grid current can be cut down until it reaches a value at which the absorption of power in the grid circuit becomes less than the power which the circuit furnishes on account of the regenerative effects. The circuit then begins to oscillate, and to stop it from oscillating the grid bias must be reduced. These effects are very noticeable in radio-frequency amplifiers where the high frequency makes the effect of the tube capacities considerable in allowing feed-back to take place. The proper adjustment of the grid potential is generally obtained by means of a potentiometer used in conjunction with the "A" battery; in many cases this is not sufficient, and it becomes necessary to use a "C" battery with the potentiometer.

CRYSTAL DETECTORS

The Various Types and their Operation

Galena is chemically known as sulphide of lead. In the native form it occurs in cubic or octahedral crystals, or massive. The cubic form is generally used for radio detectors. Galena is the most used of all the crystals and is perhaps the most sensitive.

Chalcopyrite is a bright, brass-yellow sulphide of copper and iron, sometimes occurring in crystal form but usually occurring massive. It is one of the most important ores of copper. As a detector it is used in contact with zincite, described below, in the perikon detector.

Bornite is also a sulphide of copper and iron, but is copper-red or brownish in color on a fresh fracture. The combination of bornite in contact with zincite is called the "perikon" detector. See also chalcopyrite.

Molybdenite is a sulphide of molybdenum, occurring in foliated masses or scales resembling graphite, but differing from the latter in its bluer color.

Zincite is a native zinc oxide, deep red to orange-yellow in color, usually occurring in massive or granular form. Used in contact with chalcopyrite or bornite described above, it is known as the "perikon" detector. This detector is very sensitive and many persons prefer it to the ordinary galena detector. The two minerals are mounted in separate cups and brought into contact.

Cuprite is a native oxide of copper, occurring crystalline or massive. It is not especially valuable as a detector, but is important as a copper ore.

Silicon is another of the elements used as detectors. It is never found free, although, next to oxygen, it is the most abundant element of all. It is a silvery, metallic appearing substance, highly crystalline and very brittle. It is a rather sensitive detector, perhaps not as sensitive as galena, but the adjustment is not nearly as critical. The combination of silicon and antimony is sometimes used, and forms a very sensitive detector.

Antimony is another of the elements used as radio detectors. It has a metallic appearance and crystalline structure, tin-white in color, hard and brittle. It is used in combination with silicon, described above.

Pyrite, iron pyrite, sometimes known as fool's gold, is a sulphide of iron, and has been used considerably on shipboard, since a heavy contact with the crystal is required. It occurs in cubic form, pale brass-yellow in color, brilliant metallic luster.

Several synthetic crystals have recently been placed on the market which seem to be very sensitive and possess good rectifying qualities. The oldest of the synthetic crystals is **carborundum.** It is a beautiful crystalline compound, a silicide of carbon. The commercial article is dark colored and iridescent.

Some of the rarer elements are also used as detectors, such as tellurium, arsenic and boron. Crystals of tellurium and arsenic are rare, and non-metallic boron is never found free in nature.

Theory of Operation

No satisfactory theory of operation of crystal detectors has as yet been worked out, although extensive experimenting has been done along this line for quite a few years. Many interesting questions arise in connection with the phenomenon. Some of the suggested answers that have been given are as follow.

Experiments on a carborundum crystal extended over a period of several months have indicated that if there is any electrolytic action, it must be of such a character as to change the nature of the electrodes or of the crystal only very slowly, if at all. This conclusion was arrived at by taking measurements of the current through the detector in either direction under various voltages, daily, and all through the test there were no changes in values above one-third of one per cent, which was the limit of accuracy of the measurements.

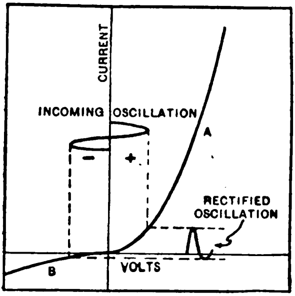


Fig. 1

Many persons still hold to the idea of thermoelectric action as the cause of the rectifying properties of crystals, even though there are many experimental facts to exclude this hypothesis. Prof. G. W. Pierce has made lengthy experiments in connection with this, and has shown that there are no actions occurring peculiar to crystals that could not be accounted for by the usual constants of the circuits, such as inductance and resistance. He has also shown that the amount of heat associated with rectification accounts for less than 1/500,000 of the rectified current as thermoelectric. Moreover, in twelve cases out of thirteen tried, the small current which might be due to thermal effects is opposed in direction to the rectified current.

The operation of a crystal detector depends upon the phenomenon of unilateral conductivity and the curvature of the characteristic. Figure 1 shows the general shape of the characteristic curve. When the voltage is applied to the crystal in one direction, we obtain the branch A of the curve, giving the values of current for the various voltages. When the voltage is applied in the other direction, we obtain the branch B. Here the current is indicated as negative, since it is in the opposite direction. For equal voltages in the opposite direction,

the current through the detector is greater when in one direction than when in the other.

The resistance of a conductor, by Ohm's law, is given by the ratio of the voltage across the terminals to the current through the conductor. If this law be applied to the branch A of Figure 1 it will be noticed that the current increases more rapidly than the voltage, which means that the resistance decreases as the voltage increases. It is this decrease in resistance upon which the operation depends. No explanation for this phenomenon has yet been found.

There is another condition required for a crystal to operate as a detector: its conductivity should vary as different voltages in the same direction are applied. This property depends upon the curvature of the characteristic curve, which also determines whether or not an auxiliary or "booster" battery need be used with the crystal. This booster voltage is placed in series with the detector and is adjusted so that the crystal operates at the sharpest bend of the characteristic curve.

The action of the battery can be explained by reference to the curve of resistance shown on following page. As the voltage impressed on a crystal is increased, its resistance decreases rapidly, or, what is the same thing, its conductivity increases rapidly; therefore, for a given oscillating voltage induced in the circuit by incoming radio waves, if we add to this the proper voltage from the local source, the current resulting from the waves will be much greater in value than if the resistance of the detector were higher. There is always the constant flow of current in the circuit due to the local emf, and superposed upon this is the oscillating current. Using a higher voltage not only increases the total current in the circuit but increases the amplitude of its variations which result from the incoming oscillating voltage. Figure 2 shows the connections for a potentiometer for regulating the booster voltage.

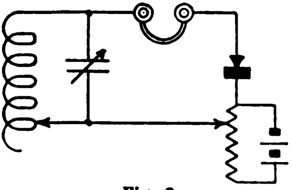
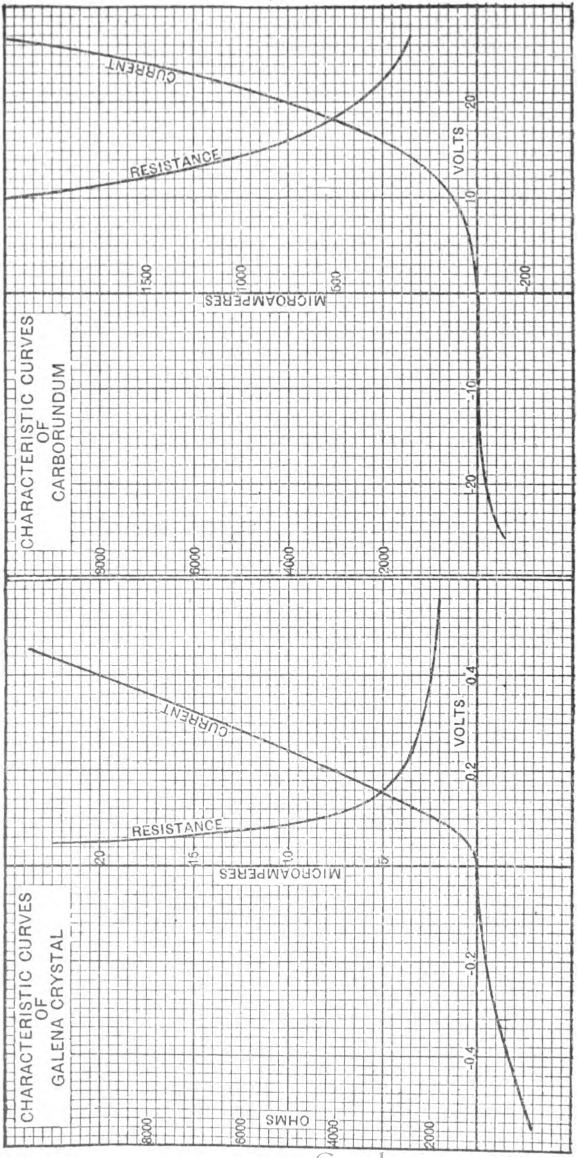


Fig. 2

The effect of using the proper booster voltage, then, is to cause operation at the bend of the characteristic curve, resulting in rectification due to the curvature, and also to reduce the resistance of the crystal so that the current flow resulting from the oscillating potentials is greater. Many crystals do not require an auxiliary voltage. Among these are galena, silicon, zincite-bornite. Carborundum will work without it, but works better with it. Characteristics of carborundum and galena are shown on the following page.


CHARACTERISTIC CURVES
OF
CARBORUNDUM
CURRENT
RESISTANCE
VOLTS
MICROAMPERES
20
10
-10
-20
1500
1000
500
200
8000
6000
4000
2000
CHARACTERISTIC CURVES
OF
GALENA CRYSTAL
CURRENT
RESISTANCE
VOLTS
MICROAMPERES
OHMS
0.4
0.2
-0.2
-0.4
20
15
10
5
8000
6000
4000
2000

SUPPLEMENTAL LIST OF BROADCASTING STATIONS TO AUGUST 29, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFDL	Knight Campbell Mus. Co.	Denver, Colo.......	1330	226	5
KFIQ	First Methodist Church...	Yakima, Wash.....	1240	242	50
KFLR	University of New Mexico.	Albuquerque, N. M.	1180	254	100
KFOF	Rohrer Elec. Co..........	Marshfield, Ore.....	1250	240	10
KFQY	Farmers State Bank.......	Belden, Nebraska...	1100	273	10
KFQZ	Taft Radio Co............	Hollywood, Calif....	1250	240	250
KFSY	The Van Blaricom Co.....	Helena, Mont......	1150	261	10
WABN	Ott Radio, Inc............	La Crosse, Wis.....	1230	244	500
WEBI	Walter H. Gibbons.......	Salisbury, Md......	1240	242	15
WEBK	Grand Rapids Radio Co...	Grand Rapids, Mich	1150	261	20
WFBB	Eureka College...........	Eureka, Ill.........	1250	240	50
WFBG	Wm. F. Gable, Co........	Altoona, Pa........	1150	261	100
WNAL	Omaha Central High School	Omaha, Nebr.......	1160	258	20
WNAR	First Christian Church....	Butler, Mo.........	1300	231	20

Changes

KFBC—power decreased to 5 watts.
KFID—power increased to 30 watts.
KFLD—power decreased to 10 watts.
KFQH—Radio Service Co., Burlingame, Calif.
WBAO—1090 kilocycles, 275 meters.
WBBP—power increased to 100 watts.
WDAP—Call changed to WGN—810 kilocycles, 370 meters.
WEBP—New owner—Spanish Fort Amusement Park—1070 kilocycles, 280 meters, 50 watts.
WFAN—1050 kilocycles, 286 meters.
WFAV—power decreased to 250 watts.
WGAQ—New owner—Youree Hotel.
WIAO—call changed to WSOE.
WRW—power increased to 500 watts.
WWL—power decreased to 5 watts.

Licenses Recently Cancelled

KDZI	KFIQ	WABT	WDBK	WLAV	WSAN
KFEV	KFNX	WBBA	WFAH	WNAL	WTAG
KFEZ	KFPQ	WBBJ	WGAW	WNAR	WWAB
KFFX	KFPS	WDAK	WIAY	WOAH	WWAE
KFIL	WABG	WDBG	WJAQ	WQAL	WWAO

Note:—Three calls listed among the cancelled licenses have been reassigned to new owners, as shown at top of page. These calls are KFIQ, WNAL and WNAR. Bringing this to the attention of our readers may prevent confusion.

RADIO FORMULAS

Distributed through the former issues of Radiofax are many valuable radio formulas, each accompanied with considerable descriptive matter aiming to thorougly explain its use.

Many of our readers, having become proficient in the application of these formulas, have urged that we reprint them grouped together for ready reference, and devoid of text. This plan would allow them to insert all the equations in their book without increasing its thickness by more than two sheets.

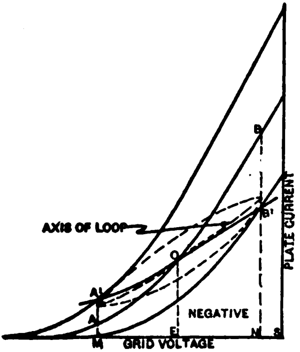
As a result of this suggestion we will publish such a compilation in the October issue.

DYNAMIC CHARACTERISTICS

The characteristic curves of vacuum tubes with which most of us are acquainted are the static characteristics, that is, the curves obtained by impressing on the tube steady plate potentials and observing the steady plate currents. Two kinds of static characteristics may be drawn—one kind for a resistance in the plate circuit which is negligible compared with the resistance of the tube, and the other for an appreciable or large resistance in the plate circuit. The curves tend to straighten out as the plate circuit resistance is increased, but for a given value of plate current, as the external resistance is increased the amplification constant drops. Thus we can obtain distortionless reproduction of wave shape through the tube at the expense of the amplification. Static characteristics of an unloaded tube are shown in each of the articles on the various types of tubes that appeared in former issues of Radiofax.

When alternating potentials are impressed on the grid, as is the case in reception of signals, the characteristics sometimes take a decidedly different form, and are known as dynamic characteristics. There are three cases to consider: the characteristic of the tube itself, that of the plate circuit containing the tube and non-inductive resistance, and that of the circuit containing tube and reactance.

The dynamic characteristic of the tube itself (external impedance negligible, and neglecting tube electrode capacity) coincides with its static characteristic. If an external non-inductive resistance is in the circuit, the dynamic characteristic of the tube coincides with the static characteristic for the case of resistance in the plate circuit.



The effect of the external resistance on the characteristic of the circuit may be explained as follows:

Referring to the figure, let us suppose that the tube is operating on a certain plate voltage. The static characteristic of the circuit containing a non-inductive resistance at this voltage is the curve AOB. Let the line EO be the axis of the voltage of the oscillations impressed on the grid. The length of the line EO gives the plate current when the alternating voltage on the grid is zero. The impressed oscillations are symmetrical so that their amplitudes on either side of EO are equal,

that is, ME is equal to NE. The output currents are represented by the lines MA and NB.

As the plate current flows through the resistance, a drop in potential occurs, so that the voltage on the plate is not now equal to the voltage of the B battery. The plate voltage is decreased by an amount equal to the voltage drop in the resistance.

That is, if the plate voltage were not decreased, the value of plate current would be NB when the grid voltage is SN. The plate voltage has decreased, due to the resistance drop, so that now the point B must drop down to another characteristic curve corresponding to the lower voltage, as at B′. Likewise when the grid voltage is SM, the plate current would be MA if the plate voltage did not change. The current in the plate circuit has now decreased, however, so that the voltage drop through the resistance has also decreased. The voltage on the plate is now higher than it was, so that the tube is operating on a characteristic above the original one, as at A′.

The result is that the tube operates on a characteristic represented by the line A′B′. This is a simple line when the external resistance is non-inductive. When there is reactance in the plate circuit, the characteristic is a loop, as indicated by the dotted line in the figure. This is due to the fact that the plate potential lags behind the grid potential. When the reactance is smaller in comparison with the resistance, the loop narrows down and its axis rotates, until, when the impedance in the circuit is purely non-inductive, it degenerates into the line A′B′.

The axis of the loop, or the line into which it degenerates, is generally curved. This curvature causes distortion when amplifying oscillating currents, so to avoid distortion the amplifier must be operated under such conditions that the line becomes linear or nearly so. When the external impedance is made equal to the external output impedance of the tube, the characteristic will be substantially linear if the external reactance is less than the resistance. In cases where the reactance must necessarily be greater than the resistance, the dynamic characteristic may be straightened by making the external impedance greater than the impedance of the tube. Quality of transmission is thus gained at the expense of amplification. The sacrifice in amplification is not great, however, and is small when the external impedance is even twice as great as the plate impedance.

AVAILABLE RADIO LITERATURE FOR SEPTEMBER

A wealth of useful radio facts can be obtained from a careful reading of the pamphlets and bulletins offered to the public by the manufacturers whose reputation for dependable statements has been well established.

A list of such publications is given below. All are free for the asking, and we are sure our readers will feel well repaid for the effort required to add them to their radio data.

"Battery Charging with a Motor-Generator Set." The Ohio Electric and Controller Co., 5906 Maurice Ave., Cleveland, Ohio.

New Radio Booklet 15-A describing the Jewell Radio Measuring Instruments. Jewell Electrical Instrument Co., 1640-50 Walnut St., Chicago, Ill.

Fully Illustrated Booklets on Radiotrons and Radiolas. Radio Corporation of America, Dept. 558, 233 Broadway, New York City.

Descriptive Circulars on Crosley Radio Sets. Also, "Simplicity of Radio" by Powell Crosley, Jr., Crosley Radio Corporation, 813 Alfred Street, Cincinnati, Ohio.

AmerTran Circular 1005-A gives valuable A. F. Transformer Data. American Transformer Co., 182 Emmet St., Newark, N. J.

Bulletins Nos. 3015 and 3011-BV, describing the Audiophone Loud Speaker and Bristol One-Stage Power Amplifier. The Bristol Co., Waterbury, Conn.

"Principles of Operation of the Balkite Battery Charger." (Booklet with pages punched to fit Lefax Binders). Fansteel Products Co., Inc., North Chicago, Ill.

"20-Point" Folder on Laboratory Type Condenser. Bremer-Tully Mfg. Co., 539 S. Canal St., Chicago, Ill.

Catalogue describing "Bestone" radio parts, and literature on "Bestone" V-60 Supertoned Receiver. Henry Hyman & Co., 476 Broadway, N. Y. C.

"How the Simplex Handy Charger Keeps the Radio Set Alive." Interesting booklet by Interstate Electric Co., St. Louis, Mo.

Booklet on Saturn Automatic Radio Plug and other Saturn Products. Saturn Mfg. & Sales Co., Inc., 48 Beekman St., N. Y. C.

Illustrated Booklets on "Insulate" and Molded Insulation Products. General Insulate Co., 1008-1024 Atlantic Ave., Brooklyn, N. Y.

Complete and fully illustrated Bulletins of Electrical and Radio Laboratory Apparatus, General Radio Co., Cambridge, Mass.

"The Metalectric Soldering Iron."—folder discussing merits of this "lead-pencil size" Soldering Iron. Post Electric Co., 125 Harris Ave., Long Island City, N. Y.

Please refer to RADIOFAX when you write.

THE CRYSTAL AS A GENERATOR AND AMPLIFIER

The research work of O. Lossev of Russia, as recently reported in a series of articles published in *The Wireless World* of London, has brought to light many new facts regarding crystals. Of most importance he has shown that a crystal when used in the proper circuit can be made to oscillate. The following data represents a brief digest of the above-mentioned articles.

The best results were obtained with a zincite crystal used in conjunction with a carbon contact. With a good zincite crystal, oscillations were maintained with unvarying frequency and amplitude for more than three days.

The characteristic curve of a crystal can be obtained by connecting it in a circuit as shown in Fig. 1. The detector is shown at D. The galvanometer A measures the strength of the current which passes through the crystal. A resistance R of about 100,000 ohms is inserted, as shown, in order that voltage measurements may be made with the galvanometer V. A resistance of 1,000 to 5,000 ohms is shown at R1. A potentiometer P of approximately 800 ohms resistance is shunted across the battery B. The necessary inductance and capacity are shown at L and C.

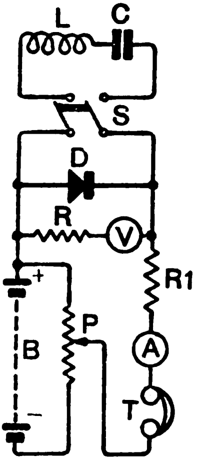


Fig. 1

If it is desired to find the generating point on the crystal shown at D, it is necessary first to close the switch S and to adjust the potentiometer so as to put 6 to 12 volts on the detector. By searching the different points on the crystal with the contact wire, the generating point will be found when a note is heard in the telephones. If the point is a sensitive one, the note remains pure and steady and does not change in tone. The points which are suitable for detecting are generally not the best for generating purposes.

By opening the switch S the characteristic of the detector can be obtained by increasing the applied voltage from zero by equal steps through the agency of the potentiometer. For each change on A the value of the

current i is noted and the corresponding voltage is read on V. After reaching a current reading of about 5 to 6 milliamperes the measurements can be plotted on cross-section paper, as shown in Fig. 2.

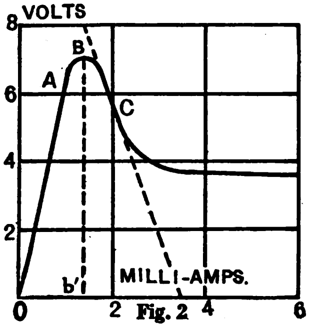


Fig. 2

Between the points OA the resistance remains approximately the same. It then diminishes and becomes zero at point B. When the current is increased beyond this point the resistance becomes negative. The steeper the slope of the curve, the greater will be the change of resistance values. When the current is increased from O to B, the crystal will absorb energy equal to i^2 R. After the current passes over the point B, the absorption of the energy is equal to i^2 (—R) or i^2R will become negative, which means, that the energy will no longer be absorbed, but will, on the contrary, be added to the output, so that the detector becomes a source of energy. If an alternating current is present in the oscillating circuit LC of Fig. 1 when the potential is adjusted on the detector contact so that the detector works on the steep portion of the characteristic, then the detector commences to amplify the oscillations in LC, maintaining and increasing the oscillating current.

This effect can, obviously, only be produced when the detector is operating upon the negative portion of the curve. Thus, by suitably adjusting the applied potential, it is possible to attain such a state of balance that on the one hand the received oscillations are amplified, and on the other the amplified oscillations take place partly in the position of the negative and partly the positive resistance, when a simultaneous operation of amplifying and detecting can be obtained with the same crystal.

Mr. Lossev advances the theory that generation is caused by a microscopical arc which occurs when the conditions applying are those at B in Fig. 2. The electrodes of the arc are not incandescent, and the temperature rise at the point of contact does not exceed 100° C. Only small discharges take place across the gap around the contacts, which has the effect of deflecting the initial part of the characteristic curve from a straight line.

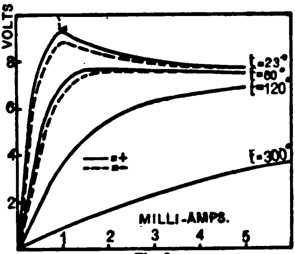


Fig. 3

The curves in Fig. 3 show how an increased temperature decreases the oscillating properties of a zincite—steel wire detector. The temperatures are in Centigrade degrees. The two curves drawn with solid lines at the top of the chart are plotted with the positive side of the applied current to the steel wire. The dotted curves show the effect when the positive is on the zincite. The two lower curves indicate no change in conductivity with current reversal.

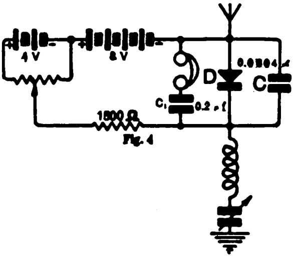


Fig. 4

A circuit in which a zincite detector serves simultaneously as a generator of continuous waves and as a detector is shown in Fig. 4. The condenser C_1 serves to prevent the direct current from the battery from passing through the telephones. It will, however, offer no obstacle to the detected pulsating current.

With the proper circuit arrangement and adjustment of controls, transmission over a distance of one mile has proven possible with an oscillating crystal. On both sides the crystal will serve as a generator and detector, thus apparently making duplex transmission possible.

These investigations are still only of theoretical interest, for the vacuum tube is so far superior to the crystal as an amplifier and generator that it is unwise to make a comparison lest the reader be led to believe that the crystal will soon displace his tubes. The chief value of Mr. Lossev's investigations lies in the fact that we now are in possession of new data which may bring nearer the solution of the old question—why does a crystal rectify?

TUBE CHARACTERISTICS
UV 201-A

Due to continued effort to improve the performance of the UV 201-A tube, it is now necessary to present new data superseding those given in the table on page 34 of Radiofax for April, 1924. It will be noted that very material changes have been made in the mutual conductance and in the amplification factor.

MUTUAL CONDUCTANCE
(Micromhos)

For zero grid and 5 volts on filament

Plate voltage	20	40	60	80	100	120
Mutual conductance	235	480	650	765	860	920

For plate voltage 100 and 5 volts on filament

Grid voltage	+2	0	—2	—4	—6	—8
Mutual conductance	970	860	800	710	610	485

For plate voltage 40 and 5 volts on filament

Grid voltage	+2	0	—2	—4
Mutual conductance	675	480	290	90

PLATE IMPEDANCE
(Ohms)

For zero grid and 5 volts on filament

Plate voltage	20	40	60	80	100	120
Impedance	32000	16500	12200	10400	9200	8800

For plate voltage 100 and 5 volts on filament

Grid voltage	+2	0	—2	—4	—6	—8	—10
Impedance	8600	9200	10000	11200	13300	16900	23600

For plate voltage 40 and 5 volts on filament

Grid voltage	+2	0	—2	—3	—3½
Impedance	13400	16500	24000	32400	38200

AMPLIFICATION FACTOR

For zero grid and 5 volts on filament

Plate voltage	20	40	60	80	100	120
Amplification factor	7.95	8.00	8.02	8.05	8.06	8.07

For plate voltage 100 and 5 volts on filament

Grid voltage	+2	0	—2	—4	—6
Amplification factor	8.08	8.06	8.05	8.04	8.00

For plate voltage 40 and 5 volts on filament

Grid voltage	+2	0	—2	—4	—6
Amplification factor	7.98	8.00	7.97	7.87	7.67

1.5 microfarads in series with the primary winding tuning L_1 to about 300 cycles per second.

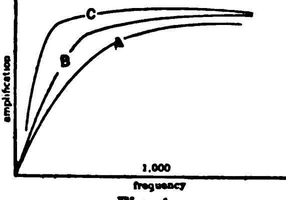


Fig. 4

It is seen that curve A suppresses frequencies below 1,000 cycles and is therefore unsuitable for a speech amplifier. Curve B is a decided improvement over A for work at lower frequencies. The use of the condenser improves the transformer for frequencies above 200 cycles and is then better as a speech amplifier than the transformer alone. The effect of distributed capacity may then be counteracted by decreasing the turn ratio or by inserting an inductance in series with the primary. It may be stated that in general the lower the ratio of the transformer the better it will be suited to a wide range of frequencies. Care must be taken to choose a transformer best suited to the tube.

The question now arises—why not decrease the number of primary turns and thus decrease the number of secondary turns for a given ratio, thereby lowering the distributed capacity? As a matter of fact there is a minimum number of turns which should be used on the primary winding. The maximum voltage across the primary will be developed when the reactance of the coil equals about three times the tube resistance in the primary circuit. Theoretically, maximum voltage is developed across the coil when the reactance is infinite, but the practical limit is found to be just as stated above. For a lower value of reactance the voltage developed is less than maximum.

The reactance X is calculated from $X = 2\pi fL_1$ where L_1 is the inductance. And L_1 is proportional to the number of turns on the winding and the flux linking the winding. The curves in Fig. 4 pointed to the fact that a high inductance gives better amplification at low frequencies. Since we must not increase the number of turns in the coil, it will be necessary to increase the flux in the core of the transformer to give us the required high inductance. Let us study Fig. 5 a moment.

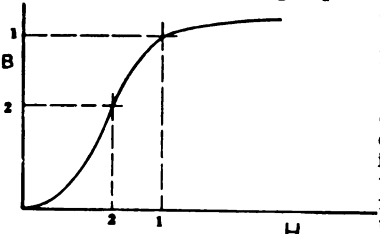


Fig. 5

This curve is called a B and H curve. All samples of iron and steel have curves of this general character, which are alike for every like sample of iron. The vertical axis of the curve is labeled B or units of flux

density, i.e., so many lines of flux per unit area of cross-section of iron. The horizontal axis, H is measured in units of magnetizing force or ampere turns. For instance, H_1 ampere turns around a certain core always produce B_1 lines of flux per square inch in the core. Note that above a certain flux density B_1 no matter how many more ampere turns are added the flux density is not increased. At B_1 the iron is said to be magnetically saturated.

Also note that there is a portion of the curve which is very nearly a straight line where B varies directly as H. If for any reason the core is magnetized to the point B_1 then distortion results because equal changes in magnetizing force do not produce like changes in the flux threading the secondary coil. Suppose, however, the size of the core is increased to 2 square inches. The flux linking the coils can now be produced at a much lower flux density. The ampere turns can also be decreased to H_2 to give this new value of B_2. At this point no distortion occurs because of saturation and very little from distributed capacity because the windings are much smaller. The inductance is still high enough to give good amplification at low frequencies and the capacity is low enough to give good amplification at the higher frequencies.

As a result of this survey we may conclude that the size and weight of a transformer may be taken as a measure of its quality. The more active iron in the core the better it is suited for audio amplification. Very small transformers are bound to be poor. They may be excellent instruments at one fixed frequency, but for radio broadcasting they are unsuited. A few manu-

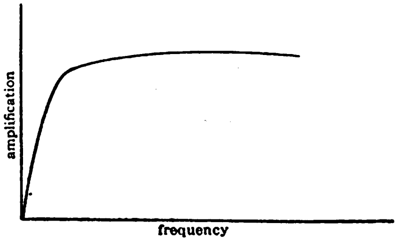


Fig. 6

facturers have begun to realize this fact and have produced good transformers. One manufacturer claims a characteristic curve as shown in Fig. 6 for his instrument. If the curve is true, then a big step towards the solution of the distortion problem has been made.

The reader must bear in mind that all the distortion is not caused by the transformer. Poor tubes, poor phones and loud speakers or poor batteries are also often to blame.

THE AUDIO TRANSFORMER

A few years ago the average radio fan possessed but a simple crystal set. His one aim was to obtain the maximum possible volume and receiving range at the least expense. These two factors governed to a great extent the design and application of the various electrical devices in the radio field. The advent of the vacuum tube presented the problem of the coupling in the most efficient manner possible of two or more vacuum tube circuits. Telephone and telegraph companies were using transformer-coupled tube circuits, and the radio fan soon attempted to adapt these devices to his own requirements. What was the result? As soon as radio broadcasting made its appearance manufacturers attempted to supply the enormous demand for equipment. The public had gone wild over the idea of volume and distance with no regard for quality and consequently much inferior equipment was placed on the market. It was realized that an audio transformer was necessary and so the design was borrowed from the telegraph companies. No attention was paid to the fact that a transformer suitable for use in a telegraph circuit might possibly be decidedly unsuited to the radio circuit. To understand what harm might result from such a blind application, it will be necessary to study the theory of the audio transformer.

What are the duties of this instrument? First of all, it must reproduce in the secondary circuit whatever changes in current or voltage take place in the primary circuit. All direct and unvarying currents in the two circuits must be isolated in some instances and the transformer will do this. Frequently the voltage impressed across the primary terminals must be amplified or "stepped-up" to a much higher value in the secondary circuit, and again the transformer is used as the medium. The name "audio transformer" arises from the fact that it must function at audio frequencies, namely between the ranges of 30 cycles per second and 10,000 cycles per second. This is an extremely wide band of frequencies and only an ideal transformer can function throughout such a range. If for any reason certain frequencies are lost in the transformer or the transformer produces new frequencies, then the secondary circuit does not receive a true picture of the events happening in the primary circuit.

Let us study Fig. 1 a moment. Here is shown the voltage characteristic of the ideal audio transformer. Now suppose we choose at random some audio transformer on the market and obtain the data for its voltage characteristic curve. When plotted the curve resembles Fig. 2. Evidently this is not an ideal transformer. An analysis of the curve will show what has happened. It is evidently a picture of the variation of the voltage across the terminals of an inductance con-

nected in parallel with a condenser. The peak in the curve is caused by the resonance point being reached at one certain frequency.

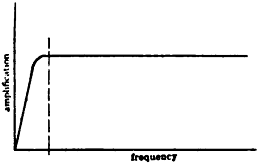


Fig. 1

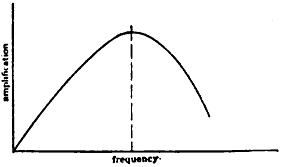


Fig. 2

This resonant frequency may be calculated from the formula, $f = 1/(2\pi\sqrt{LC})$
where L is the inductance in henries and C the capacity in farads.

This capacity effect is known as distributed capacity, and is present to some degree in all coils. Its value depends on the number of turns and also on the method of winding. The more turns on the coil the greater is the capacity. It can be seen that the value of this capacity can be controlled to some extent by the design of the coil. Of course, in the audio transformer the circuit is rather complicated and the distributed capacity can not be easily calculated. The importnat point to remember is that the capacity is present in some form and acts as if it were a condenser shunted across the terminals of the transformer. The high-frequency currents will tend to pass through the condenser and not through the winding of the transformer. The result is a muffled tone in music or speech and the absence of consonants. As an example let us assume a transformer as shown in Fig. 3. Neglecting the resistance of the winding and the capacity effect the output voltage E_2 is given by

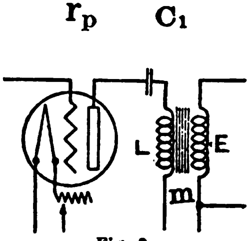


Fig. 3

$$E_2 = \frac{E_1 M 2\pi f}{\sqrt{R^2 + X_1^2}}$$

where E_1 is the input voltage, M is the mutual inductance between the windings, X_1 is the reactance of the primary winding and R is the impedance of the tube on the primary circuit. It is assumed that the grid impedance of the secondary circuit is infinite.

The curves in Fig. 4 are plotted from this equation. R is 5,000 ohms in each case. Curve A corresponds to an inductance of 1 henry and curve B to an inductance of 2 henries. Curve C has a condenser of about

ADVANCE

CHAPTER SIX

LINES OF ADVANCE IN RADIO

Elimination of Antenna and Battery.—The radio receiving apparatus now in use in the homes has been taken over without much change from the rough and complicated type of apparatus used on ships. The first automobiles were merely wagons with engines placed in them and they had a whipstock on the dash-board. It is just as incongruous to take a storage battery into a living-room. Methods have been worked out to eliminate the storage battery. Receiving sets are already on the market that use small dry batteries in place of the storage battery. Methods for replacing the batteries entirely by connection to the alternating-current lamp socket are also known; they will doubtless shortly be manufactured and on sale.

Strictly speaking, it will never be possible to eliminate the antenna. There must always be something to receive or catch the wave and convert it into a current. Nevertheless the antenna can be made so small or in such a form that it will be as good as eliminated. As a general principle, when smaller forms of antenna are used it is necessary to have more sensitive amplifiers. One such small antenna is the coil antenna, which was explained in chapter 5, and which is mentioned again just below under "Direction Finding." Another way out is to use a mass of metal within the house, such as a metal bed, as the antenna. The same effect is attained by a connection to the electric wiring in the house as an antenna. A special connecting plug has to be used, so as to avoid short-circuiting the wiring; it is best for amateurs not to try this. All these schemes for eliminating the antenna will be more and more successful as receiving apparatus, already extraordinarily sensitive, is further improved and more widely used.

Direction Finding.—In chapter 2 it was explained that a coil antenna is directional. That is, it receives signals from stations which are in line with its plane and receives practically no signals from stations which are in a direction at right angles. This property of coil antennas is being used to an increasing extent as a method of eliminating the interference which is caused by the working of a number of broadcasting stations on practically the same wave lengths. In order to accomplish this the coil should be turned about

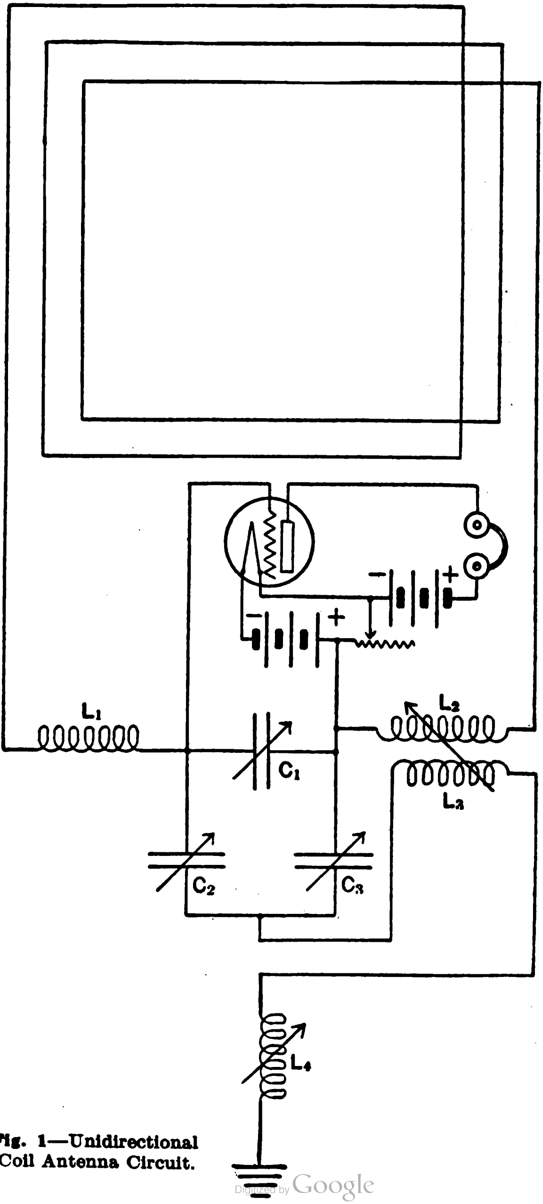


Fig. 1—Unidirectional Coil Antenna Circuit.

a vertical axis until its plane is at right angles to the station whose signals it is desired to eliminate. It will then be possible to hear stations which are in any direction within 30 or 40 degrees of the direction in which the plane of the coil lies, but nothing will be received from stations in a direction of 90°.

The coil antenna receives equally well from two opposite directions. Recent studies have indicated that it is possible to arrange a circuit which will receive from one direction to the exclusion of signals from the opposite direction. Fig. 1 shows a circuit which may be used for this purpose. Other methods are possible and it is to be expected that further experiments with combined coils and elevated antennas will greatly improve this unidirectional reception.

Sometimes it will be found that the minimum indication of a direction finder is not very sharp, but that weak signals can be heard no matter in what position the coil is turned. One cause for this may be a lack of symmetry in the capacity of the two ends of the coil to ground or to the nearby metallic base. Remedies are being developed for such troubles. One remedy is to connect a "balancing condenser" as shown in Fig. 1. This is simply a variable condenser with two sets of fixed plates and one set of moving plates, the moving set of plates being connected to the ground or to one side of the filament ("A") battery. Sometimes even the adjustment of this condenser will not secure a sharp minimum. It is then likely that the waves in the immediate vicinity of the receiving station are bent from their normal position by the proximity of electric power wires, telephone wires, or metal structures. It is an interesting experiment to take a small coil antenna and rotate it in an effort to find the position in which it receives loud or weak signals.

The coil antenna shown in Fig. 1 and the tuning condenser C_1, are of ordinary design and construction, as described on page 11 of Chap. 3. For example, the coil may consist of 6 turns of wire on a frame 5 ft. square and the condenser may be a variable air condenser having a maximum capacity of 0.001 microfarad. The three upper coils, L_1, L_2 and L_3, may have an inductance of the order of 100 to 1000 microhenries. The entire circuit, with the exception of the coupling of L_2 and L_3 should be arranged symmetrically. The lower coil, L_4, should have the proper inductance to tune the antenna to ground circuit to the wave length of the signals which it is desired to receive. An inductance of several millihenries is likely to be required, since the capacity to ground of the wire forming the coil antenna is ordinarily quite small. Instead of using the specially constructed balancing condenser, two variable air condensers may be used, as shown at C_2 and C_3. These may each have a maximum capacity of about 0.0002 microfarad.

Radio-Frequency Amplifiers.—One of the newer types of receiving apparatus referred to in chapter 2 is the radio-frequency amplifier. Since radio-frequency amplifiers are connected to the circuit between the receiving tuner and the detector they may also be tuned to the frequency or wave length of the radio signals. This gives an added opportunity for the elimination of wave lengths which it is not desired to receive. By using several stages of radio-frequency amplification, and two or three stages of audio-frequency amplification, it is possible to secure very loud signals without producing the disturbing note in the telephone receiver which is produced because of self generation of audio-frequency current when a large number of stages of audio-frequency amplification are used. When it is desired to use radio-frequency amplification with sharp wave-length tuning, transformer coupling should be used between the stages of the amplifier. If it is desired to secure rather broad tuning of the radio-frequency amplifier, it is desirable to use resistance coupling between the stages. However, resistance coupled amplifiers seldom give full amplification at frequencies above 300,000 (wave lengths below 1000 meters). For radio-frequency amplification at higher frequencies an interesting method is to have a local generating set which is coupled to the antenna circuit and which produces current of a frequency slightly different from the frequency of the signals to be received. This arrangement of apparatus is called a "heterodyne." The difference between the frequencies of the received and locally generated current should be about 100,000 cycles. Suppose the incoming wave has a frequency of 3,000,000 and the heterodyne is adjusted to give a frequency of 3,100,000, then the difference between these frequencies will be a beat current having a frequency of 100,000. This beat current can then be amplified with a radio-frequency amplifier. The output of the radio-frequency amplifier can then be treated as in the usual methods of reception. It can be detected and amplified at audio-frequencies or can be made audible by a second heterodyne. This method requires critical adjustments and considerable skill in manipulation. For further information on this method of reducing the radio frequency by the beat method, reference should be made to a paper by E. H. Armstrong, published in the Proceedings of the Institute of Radio Engineers, volume 9, page 3, 1921.

Line-Radio Communication.—It has been found that radio waves can be guided along wires between the transmitting and receiving stations instead of being radiated through space. The wires used in this way can be used simultaneously for ordinary telegraphic messages and telephone conversations, or for transmitting electric power. Various names have been

applied to this method of communication, such as "wire-radio telephony," "carrier-frequency telephony," "guided-wave telephony," and "wired wireless." Line radio telephony can be conducted by connecting a radio telephone transmitting set to one end of a wire in the same way as it ordinarily is connected to an antenna. The receiving set should be connected to the other end of the wire in a similar manner. Distances of 10 or 20 times the radio transmission ranges can be obtained with the use of a given power by this method. In connecting transmitting or receiving sets to the wire lines in this way care should be taken not to make any changes in the circuit which would affect other ordinary use. While the use of this method of communication is rapidly being extended, it is desirable that installations be made only by experts on account of the danger of interrupting the normal service of the wire lines or making wrong connections which would cause serious injury or damage.

Line radio telephony offers the additional advantage of carrying a number of messages over one pair of wires at the same time without interference. This is done by tuning arrangements at both the transmitting and receiving ends, which keep the different messages from interfering with one another. Waves guided along conductors seem bound to become more common, since trolley wires, power wires or any other sort of wires may be used to guide the waves. Thus a telephone becomes possible for every building into which electric light wires run. Furthermore, line radio telephony may be linked with or connected to ordinary wire telephony. Thus it seems unquestionable that this method will more and more supplement the regular telephone system.

While this is not really radio communication, it presents a solution to some of the problems of radio. It is a secret method of communication whereas radio is utterly public. It solves the question of communication in one direction to the exclusion of others wherever there is a guiding conductor in the direction desired.

Strays.—Attention has been called in chapter 2 to the occurrence of noises in the receiving set which are caused by atmospheric electrical disturbances ordinarily called "strays" or "static." Strays are the most serious limitation on radio communication at the present time and many methods have been devised for the purpose of minimizing their effect or increasing the strength of desired signals without increasing the strength of the undesired strays. So far none of these methods have proven to be satisfactory in the elimination of strays. The most useful means which have been developed for approaching a satisfactory solution are the use of a low directional antenna and the use of loose coupling between several sharply tuned circuits

of the receiving set. For receiving continuous waves the use of the beat method of reception is also a great advantage, but this is not applicable to radio telephone reception. The elimination of the effect of strays on radio receiving apparatus is a very important problem; it is almost as difficult as devising a method which would keep a tuning fork from vibrating when it is struck by a sledge hammer while permitting it to vibrate when it is placed in the vicinity of another tuning fork vibrating at the same pitch.

Elimination of Spark Sets.—It is desirable that the waves from a transmitting station be as nearly of a single frequency as possible. Most spark transmitting sets fall far from this requirement. As advances take place in radio and as new stations are installed these old types of spark sets will doubtless go out of use. If all the spark sets now used by ships and commercial stations and by amateurs are some day replaced by transmitting sets which will send out continuous waves, the objectionable interference in the form of dots and dashes, which many receivers of broadcast service meet at the present time, will be eliminated.

Loud Speakers.—It is often desirable that the radio telephone service obtained at a receiving station be made loud enough to be heard by a large audience or at least a room full of people. In order to accomplish this some form of loud speaker or loud-speaking reproducer is attached. Many of the present types are adaptations of the ordinary telephone receiver which is designed for comparatively weak signals and does not operate well when forced to produce loud sounds. The result is that the speech or music is impaired in quality. There are, however, a number of scientifically designed loud speakers now available capable of giving very true reproduction.

Secrecy.—At present practically all radio transmission is of such a nature as to make it impossible to keep it from being received by anyone who so desires. The law forbids the disclosing of a message to other persons than those for whom it is intended. This of course does not cover the broadcast services, for the term is to signify transmission which is intended for an unlimited number of receiving sets without charge at the receiving end. Technical methods are being developed which will make it impossible for persons to receive certain kinds of radio signals unless supplied with a special kind of receiving apparatus which is designed to match with the particular transmitting set employed. By the use of such methods unauthorized listening-in will become so difficult as to be accomplished only by persons who are experts. It is not likely, however, unless technical developments are carried very much farther than seems at all possible at

the present time, that secrecy and selectivity will be obtained to such an extent as to make feasible the simultaneous secret communication between every pair of individuals who may desire to talk with one another.

Remote Control by Radio.—With the development of amplifiers there has come the increasing possibility of using radio to control the operation of any machinery or motion at a distance, by use of a relay or switch connected to special radio receiving apparatus. In order to accomplish this, signals are transmitted by radio and are received by a receiving station employing a very sensitive amplifier and specially designed relay device. This relay is then connected to such mechanism as it is desired to operate at the receiving station. Such mechanism may be an electric light, an electric bell, the control lever of an airplane, the switch of an electric power line, or other mechanism. A disadvantage of radio control is that the receiving apparatus must be in continuous operation with consequent consumption of power from the batteries or generator which supplies current to the receiving set. For certain purposes, however, this is not too great an expense to keep the use of distant control by radio from being feasible. The use of radio in this way is being considered by a number of electric power companies for operating switches at distant power plants or stations.

Regulation of Broadcast Service.—In order that the public may have a really satisfactory broadcast service, which it is possible for it to receive and which it will demand as the utility of radio broadcasting becomes further known, it is necessary that this service be under careful supervision. Its control or regulation must be in the hands of the Federal Government, since, by its very nature, radio extends in all directions and knows no boundaries. Through suitable advisory channels the public can inform the Federal Government of the kinds of service which it desires most and if granted proper authority, the Government can establish regulations which will provide in a given community for the operation of a limited number of broadcasting stations. These stations may, for example, operate simultaneously on different wave lengths and each furnish to the public a different type of service. This would make it possible for the individual desiring to receive a certain broadcast service to push a button on his receiving set which is marked for that service. The final tuning of his set to the station which transmits this class of broadcasting can be done by a single lever or control knob. The principle of a receiving set which might be developed to fit such a condition is shown in Fig. 2. A large number of problems, both

technical and administrative, must be solved in order to make such service really satisfactory.

Uses of Radio.—It is not necessary to look to the future for extensive use of radio. It is used more extensively than most people realize for navigational aids, for communication with ships, aircraft, remote regions,

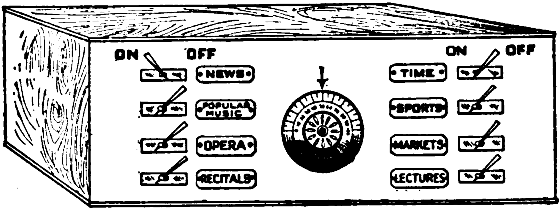


Fig. 2—Radio Broadcast Receiving Set of the Near Future.

and across the oceans. Its use on trains and all vehicles will come. Forests will be better protected by its use for instant reporting of fires. The broadcasting of news and important announcements will be accomplished and regulated with a perfection that would now seem startling. The problem in radio, will, indeed, be to restrict its uses enough to permit any messages getting through. The very need of control of the air will be a powerful factor for world organization and peace.

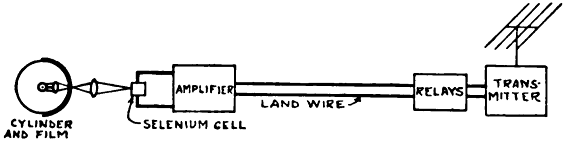
By inserting in this binder the additional sheets to be published from time to time—as fast as improvements in radio are perfected—the holder will be kept fully advised of all advances of moment in the art of radio communication and will thus be enabled to maintain his equipment at maximum efficiency.

TRANSMITTING PHOTOGRAPHS BY RADIO

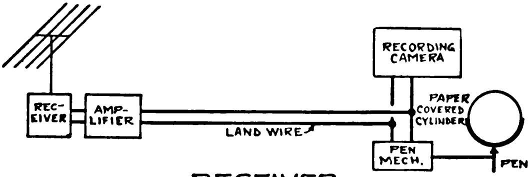
The recent demonstration of a method for transmitting photographs by radio across the Atlantic is of sufficient importance to justify the addition of a few pages to the chapter "Lines of Advance."

The experiment was the outgrowth of intensive laboratory work by the Radio Corporation of America, under the guidance of Capt. R. H. Ranger. It represents perhaps the nearest approach to the solution of this old problem that is possible within the limitations of our present knowledge.

The method by which the transmission was effected is shown in the following sketches: The picture to be transmitted is first photographed upon an ordinary film which is developed and fixed in the usual way.



TRANSMITTER



RECEIVER

This film is placed on a glass cylinder arranged to rotate at a definite speed. Inside of this cylinder is mounted an electric lamp, the light from which is concentrated by a lens into a minute beam coming to a focus on the film. The ray, as it emerges from the film, is again brought to focus on a selenium cell.

The selenium cell is a device for taking advantage of a peculiar property of selenium discovered a long time ago. This element which resembles sulphur is found in many copper ores. When an attempt is made to pass a current of electricity through a piece of selenium, it would be cataloged as a conductor or a non-conductor, depending upon whether it was or was not exposed to light at the time. In the dark, selenium is practically an insulator, but when exposed to light its resistance decreases and this lowering of resistance is greatest when the light shining on the selenium is most intense.

The cylinder is so moved that the small beam of light eventually touches every part of the film. When a dark part falls in the path of the beam, no light is

thrown on the selenium cell and consequently no current flows in its circuit. When a clear part of the film comes before the beam the light is not obstructed and is projected on to the selenium cell, reducing its resistance and thus permitting a current to flow. Intermediate values on the film cause a proportionally smaller amount of current in the selenium cell circuit.

These pulsations of current are amplified by means of ordinary electron tubes and the output is transmitted by land wire to the broadcasting station. Here the pulsations are passed through special relays. These relays convert the pulsations into dots, dashes and spaces, which are immediately sent out by the broadcasting apparatus.

At the receiving end these dots and dashes are picked up by a long antenna and fed to an electron tube receiver and amplifier. The output of the amplifier is transmitted by land wire to the place where the picture is to be reproduced.

Here the current pulsations are caused to actuate two separate mechanisms. One of these is a recording camera. This is practically a duplicate of the transmitting device. A film is caused to move about across the path of a small beam of light, the intensity of which changes in accord with the value of the similar beam at the transmitter. This film can then be developed and used in the ordinary way.

The other apparatus consists of a moving cylinder carrying a sheet of white paper and a magnetically-operated pen which, actuated by the dots and dashes of the transmitter, draws upon the paper a copy of the original photograph.

The faithfulness of reproduction depends upon absolute synchronism between the moving parts of the transmitter and receiver. Two identical motors are used to accomplish this aim, and their speed uniformity is continually checked and controlled by a special mechanism making use of the constant pitch of a vibrating tuning fork.

The results obtained by this method of photograph transmission are far from perfect. The comparatively large space between the impressions made by the pen preclude the showing of detail. A very good general idea of the original picture is given, however, and as stated before, the approach to the ideal is probably as close as our present store of scientific facts will permit.

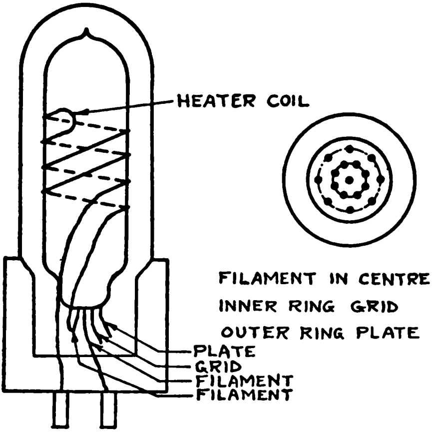
Early efforts in directive aviation proved futile until the invention and improvement of the internal combustion engine. In a like manner it seems we will have to await future discoveries in our research laboratories before perfection can be expected in television.

THE NEW SODION TUBE

Another step has been made in the development of the Sodion tube. Its new form is vastly different from the original tube, although the basic principle—the use of sodium vapor to give sensitivity—has been retained. The first tube employed metallic sodium, which was heated to attain the necessary concentration of vapor. This tube was so designed as to necessitate use in an inverted positon.

Toward the end of 1923 H. P. Donle of the Connecticut Telephone and Electric Co. announced an improved form of the Sodion tube and gave a thorough explanation of its operating principles. The November, 1923, issue of Radiofax carried a comprehensive digest of Mr. Donle's paper.

Much publicity was given the improved tube, but because its use necessitated special circuit arrangements and a non-standard socket its widespread adoption was greatly hindered.



The latest development is a tube with a standard base and requiring for its use no changes in the wiring of a set. The new tube and its predecessor both contain the correct amount of sodium in the form of vapor, and a heater is provided by means of which the temperature and pressure of the vapor is maintained at the proper operating value.

The type of tube on the market last year and known as the S-13 was widely advertised as the "Golden Rule Tube," because it was impossible to make it oscillate. It could therefore only be used in a non-regenerative circuit. The new tube can be made to oscillate smoothly when the proper values of "A" and B"" voltage are employed.

The new tube, as shown in the sketch, consists of an outer shell of frosted glass completely covering the active inner tube and serving to protect it against temperature changes due to air currents. The space between the outer and inner tube is not evacuated.

The inner tube contains the sodium vapor. In it is mounted the filament, grid and plate. The filament is a single tantalum wire running vertically through the center of the tube. Around the filament is a row of vertical wires constituting the grid. External to and concentric with the grid is another row of vertical wires forming the plate. The plate wires are arranged so that they are opposite the spaces between the grid wires. The internal structure can be more easily grasped by reference to the right-hand view in the above sketch.

Wrapped around the outside of the inner tube is a coil of wire known as the heater. This wire is connected in series with the filament, as shown. It is this coil which maintains the sodium vapor at the proper operating value.

Both the old and new style of Sodion tube are intended solely for detection, and should not, therefore, be compared with the standard tubes as audio or radio amplifiers. However, since the function of the detector is unquestionably the most important one in a receiving set there is a strong appeal for a tube of maximum sensitivity.

The new form of the Sodion tubes will make it possible for many radio experimenters to familiarize themselves with the characteristics of tubes containing sodium vapor with no greater effort than that required for removing and inserting an ordinary detector.

Note: When $\omega = 4 \times 10^6$ then

$$-\frac{1}{\omega C} = -\frac{1}{4 \times 10^6 \times 0.0005 \times 10^{-6}} = -500\Omega$$

This curve is drawn as C. Since the reactance is negative it is below the horizontal axis. A positive reactance is drawn above the horizontal axis. Hence we may conclude that a reactance diagram drawn above the axis represents an inductive circuit and a diagram below the axis represents a condensive circuit.

In radio work a coil and condenser, such as the ones just mentioned, are often connected in series and the combination used as the antenna circuit tuning elements. Let us then combine the two reactance diagrams into one diagram by adding the two curves together. Curve B shows the result. The addition may be done by a pair of dividers or a scale. The resultant curve crosses the horizontal axis at $\omega = 3.16 \times 10^6$. This point represents a frequency of 504 kilocycles. The condition for resonance is that the resultant reactance must be equal to zero. Hence at $\omega = 2.16 \times 10^6$ the series circuit is resonant and the current is a maximum. If a station is broadcasting at this frequency, it will be received, but all stations above this frequency or below this frequency will not be received because the reactance of the circuit is too large. It will be noticed that as L increases the reactance diagram for ωL rotates counter-clockwise and the resonance point moves closer to the origin. This means that a larger coil in the circuit decreases the resonant frequency (increases the wavelength). The above solution may be checked by the curves in the March issue of Radiofax.

The average tuning element consists of a fixed inductance and a variable condenser. We have chosen in our example a condenser of 0.0005 mfd. maximum capacity. As the plates of this condenser are separated, the capacity decreases and eventually reaches a minimum when the plates are entirely separated. If the reactance diagram is plotted for this minimum value and added to the reactance diagram of the coil the resultant reactance is zero at some value of ω larger than the one shown. The distance between the two zero points represents the tuning range of this particular coil and condenser.

The reader will do well to plot the diagram for an assumed minimum capacity of 0.00005 mfd., and to check the result by the curves in the March issue of Radiofax. The diagram is easy to plot if it is remembered that the reactance for this minimum capacity is ten times the reactance as shown for the condenser in Curve B. The discussion given above applies to any series circuit containing inductance and capacity.

RADIOMEN AS RESERVISTS

The Director of Naval Communications, Captain Ridley McLean, U. S. N., has recently issued orders to enlist 6,000 men in the Naval Reserve Force to be trained as naval radio operators.

It is desirable to the Navy Department that a capable force of skilled radio operators should be established, so that in any emergency radio communications may be handled in the proper manner. Members of the American Radio Relay League are particularly wanted for enrollment, but ex-service men will be given preference over all others.

The qualifications that any candidate will be required to meet to be considered elegible for this service are as follows:

First: A physical examination must be passed. This examination is similar to the examination put to prospective applicants for enlistment in the regular Navy. The Navy Department is very strict in this respect.

Second: He must be a licensed radio operator. To candidates holding operators licenses from the Department of Commerce, the following naval ratings will be issued:

License	*Corresponding Rating*
Commercial, Extra First Grade	Chief Radioman (Note).
Commercial, First Grade	Radioman First Class (Note).
Commercial, Second Grade	Radioman Second Class (Note).
Commercial, Cargo Grade	Seaman for Radioman.
Commercial, Temporary Permit	Seaman for Radioman.
Experimental and Instruction Grade	Chief Radioman, Radioman First, Second and Third Class (Note).
Amateur, First Grade	Radioman Second Class (Note).
Amateur, Second Grade	Radioman Third Class (Note).

(Note)—Provided candidate is up to Navy Speed requirements, contained in OPNAV Circular Letter 16, October, 1924.

No examinations will be necessary if a candidate holds any of the above licenses, but examinations will be held for promotions to the next higher ratings, when the Reservist is found to be qualified. High-frequency transmitting and receiving sets are to be issued to each naval district to train candidates in naval procedure, code practice, etc.

Upon enrollment the candidate becomes a Naval Reservist, class 6 and remains in an inactive status, and is not subject to call to active duty except in a national emergency.

16

The apparatus and materials described and illustrated in this section are, to the best of our knowledge, of high quality. We believe the statements made by the manufacturers thereof to be dependable. We have in most cases verified them by actual tests.

The authors, however, have been restrained by professional ethics from cooperating with us in our selection and can therefore not be held accountable for any unsubstantiated claims.

RADIOTRON UV-199

RADIOTRON UV-199, the latest addition to the Radiotron family, is the smallest tube in the line. Its overall height is 3½" and diameter is 1". The filament current consumption per tube amounts to only .06 ampere. Three ordinary number 6 dry cells connected in series are all that is required to energize the filament.

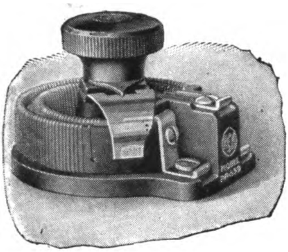
Radiotron UV-199 Price $6.50

UV-199 is not only an exceptional detector and audio-frequency amplifier but has proved to be an excellent radio-frequency amplifier, the capacity between elements being lower than that of any previous Radiotron because the plate and grid leads, and pins, are diagonally opposite instead of adjacent.

ELECTRICAL CHARACTERISTICS

Filament Battery Source	4.5 Volts
Filament Terminal Voltage	3.0 Volts
Filament Current	0.06 Amp.
Plate Voltage	
Detector	40 Volts
Amplifier	(See below)

40 Volts with 0.5 to 1.0 negative grid bias
60 " " 1.0 " 3.0 " " "
80 " " 3.0 " 4.5 " " "



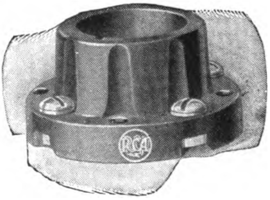
Rheostat PR-539

A new rheostat to handle from one to six Radiotron UV-199 tubes. There are two windings; both connected in series offer 33 ohms resistance for one tube—the outer one, 18 ohms for two tubes—the inner one, 15 ohms for three tubes—both in parallel, 8.2 ohms for four to six tubes.

RHEOSTAT PR-539.......................... $3.00

Socket UR-590

Socket UR-590 has been developed specially for Radiotron UV-199. The G and P connecting screws, like the corresponding pins in UV-199, are opposite instead of adjacent, making the wiring of multi-tube sets much easier, and the spring contacts are of new type, giving consistently sure, positive contact.



SOCKET UR-590............................ $ .75

Adapter UR-589

This adapter permits Radiotron UV-199 to be inserted in the standard navy type socket such as RCA Model UR-542, and takes care of the difference in the contact arrangement and the sizes of the new and old tubes. A wide, knurled ring makes it easy to grasp, insert and remove.

ADAPTER UR-589....... $1.00

KENNEDY

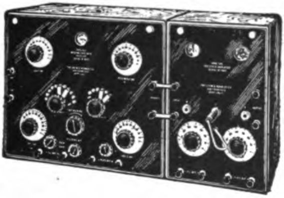
The Royalty of Radio

KENNEDY Regenerative Radio Receivers are more than mere receiving sets. Each is a beautifully finished example of handicraft that warrants it being placed in the finest homes, yet the prices are less than you would expect to pay for such scientific and artistic masterpieces.

Type-281
The "Broadcast"

The "Broadcast" Receiver, with a wave-length range of 175 to 900 meters, is specially designed for present-day broadcasting. It is extremely selective, permitting to an unusual degree the elimination of interference. Cabinet is of solid mahogany, with brilliantly polished Formica panel. Its black dials are graduated in white etching. Metal parts are heavily nickel-plated.

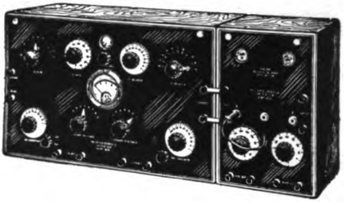
Price, Type-281 Receiver and two-stage Audio Amplifier.....$145.00
Type-281 Receiver only..... 90.00



Type-220
The "Intermediate"

This set operates with high efficiency over a wave-length range of 200 to 3,200 meters, bringing in many commercial as well as all broadcasting stations. The cabinet is of beautifully grained solid walnut; satin-finished dials inset in panel tend to outwardly reflect the character of the instrument.

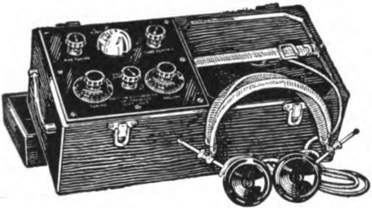
Price, Type-220 Receiver and two-stage Audio Amplifier.....$235.00
Type-220 Receiver only..... 150.00



Type-110
The "Universal"

For those desiring the finest radio receiving set obtainable—professional men, scientists, technical men, clubs, hotels, colleges, etc. —the Kennedy Universal stands supreme. It will detect, regenerate or oscillate over the entire wave-length range of 200 to 25,000 meters. It covers the entire field of radio.

Price, Type-110 Receiver and two-stage Audio Amplifier.....$370.00
Type-110 Receiver only..... 285.00



Type-311
The "Portable"

This is a handy, compact set (only 15x7½x7 inches), so easily transported that you can take it with you wherever you go—yet so beautifully finished that you will be proud to have it in your home. Highly selective, yet easily operated. It is designed for the new standard tubes, including the 1½-volt dry-cell type. When dry-cell type is used, the set is entirely self-contained, space being provided in the sturdy, beautiful oak cabinet for both "A" and "B" batteries and phones. Wave-length range, 175 to 700 meters.

Price, Type-311 Receiver, complete, with dry-cell tube, dry batteries, phones.............$75.00

Write for Descriptive Circulars

Descriptive circulars on any or all of these sets will gladly be sent on request.

Arrange for Demonstration

Any Kennedy dealer will gladly arrange to demonstrate any of these sets. If there is no Kennedy dealer near you, write to us direct for information.

All Kennedy Receiving Sets are regenerative—licensed under Armstrong U. S. Pat. No. 1,113,149.

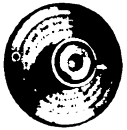
The Colin B. Kennedy Company

Saint Louis **San Francisco**

DUBILIER SPECIALTIES
For Better Reception

The Dubilier Variadon with back-of-panel mounting. In this case the dial is not supplied as a part of the Variadon. The amateur can use his own dial.

The DUBILIER VARIADON



The Dubilier Variadon as it is supplied from the factory with graduated dial and knob.

The Dubilier Variadon is a fool-proof mica variable condenser, which is no thicker than an ordinary dial but which does the work of the usual multi-plate variable air-condenser. It tunes over a scale of 340 degrees. Hence the rate of capacity increase is so low, as the knob is turned degree by degree, that a vernier is practically unnecessary. The Variadon is unaffected by body capacity effects. There are no sliding contacts. Permanent connections are made to the condenser plates. The Variadon cannot be short-circuited by shocks or falls; its adjustment is permanent. It can be mounted on the front or rear of panel. The following retail prices do not include dial for back of panel mounting.

Capacities	*Retail Prices*
.0004 mfd	$2.50
.0006 mfd	2.50
.001 mfd	3.50

Dubilier Micadons

Dubilier Micadons are small pressed mica condensers which are permanent in capacity. They are widely used in receiving sets to reduce tube howling and hence to improve the quality of broadcast reception.

Micadon type 600 is made in capacities .0001, .00025, and .0005 mfd. Price 75 cents each. In capacities .001 to .005 mfd., 75 cents to $1.00 each. .006 mfd.,$1.25.

Micadon type 601 is a small pressed mica condenser not much larger than a postage stamp. It is provided with eyelet terminals. Micadon type 601 may be connected in parallel by bolts or in series with machine screws. Price 35 to 75 cents each, depending on capacity (.0001 to .006 mfd.).

Micadon type 601 can be mounted on binding posts with special adjustable clips (ten cents extra) or provided with grid-leak clips (ten cents extra) or furnished with extended tabs 2¼" over all (ten cents extra).

Micadon type 610 is made in capacities .001 to .02 mfd., 75 cents to $1.50 each. This type has the same general characteristics as type 600, but is slightly larger.

The Dubilier Ducon Taps Lamp Sockets For Radio Concerts

The Dubilier Ducon is the standard socket plug of the world. Four hundred thousand are in use in the United States, Canada and Europe. It completely does away with the antenna. Any set can be connected with a lamp socket by means of the Ducon. Not only is the cumbrous antenna dispensed with, but the tuning is sharper than with an antenna so that simple sets become more selective. Approved by the Laboratories of the National Board of Fire Underwriters. Sold on five days' trial. Money refunded at place of purchase if not satisfactory. Price $1.50.

The Du-tec—A Synthetic Crystal

The Du-tec is a synthetic chemical rectifier which takes the place of natural crystals. Every point of the Du-tec is sensitive. Hence tedious and frequent adjustment of the "cat-whisker" is obviated. The Du-tec does not oxidize or age from exposure and does not deteriorate with high temperature. Mounted in cup ready for use. Price 30 cents each.

BRANCH OFFICES

Los Angeles, Cal. .... 329 Union League Building
St. Louis, Mo. .... Syndicate Trust Building
Washington, D. C. .... Munsey Building
Chicago, Ill. .... 33 S. Clinton Street
Atlanta, Ga. .... 302 Flatiron Building
Pittsburgh, Pa. .... 705 Granite Building
Huntington, W. Va. .... 1028 Fourth Ave.

DUBILIER Condenser & Radio Corp.
48-50 West 4th St. N.Y.

Distributed in Canada by Canadian General Electric Co. Ltd., Toronto, Canada.

England: **The Dubilier Condenser Co., Ltd., London**
Germany: **Telefunken Company, Berlin**
France: **C. Capart, Paris**

The New
Grebe Broadcast Receiver
Type CR-12

HERE is a Receiver which embodies, for the first time, the principles of Regeneration and Tuned Radio-Frequency Amplification.

You may now receive all broadcasting without outdoor antenna, loop or storage battery! A silk-covered wire but twenty feet long, supplied with this Receiver, does the work of the unsightly outdoor antenna or loop. This wire may be concealed behind the picture moulding or run along the baseboard.

Four tubes, of any type now on the market, are used. In fact, you may use a different kind of tube in each socket, and in no case do you require more than one A battery. Thus, you may use a 5-volt tube in the radio-frequency circuit, a 1½-volt tube as a detector, a 3-volt tube in the first stage and a 5-volt tube in the second stage of audio-frequency amplification.

The Receiver has only two extremely simple tuning adjustments. The secondary Tuning Dial is graduated in wave-lengths, enabling you to locate quickly a given station.

Its wave-length range—200 to 600 meters—receives all broadcasting.

You may set this receiver up immediately anywhere and anyone may, in a moment, master its simple adjustments.

The complete Receiver is contained in a beautiful walnut cabinet, attractively finished, with compartments for all necessary batteries.

There is no unsightly wiring of any kind.

Brandes Matched Tone

Reg. U. S. Pat. Off.

Superior Headsets

Here is a popular-priced headset constructed with scientific accuracy to assure perfect reception of every sound that any set picks up.

It is matched in tone so that both ears hear exactly the same sound at the same instant.

More than half a million Brandes *Matched Tone* Headsets are now in use: Which means that more than half a million people have found out just how satisfactory their receiving sets can be. Only a Brandes can do it—and do it all the time.

Impedance at 1000 cycles, approximately 20,000 ohms. Minimum current for audible signal at 1000 cycles, approximately 3.9x10.10 amperes.

LIST PRICE

Brandes Superior *Matched Tone* Headset with headband and cord........ $8.00

Distributors and Branch Offices:

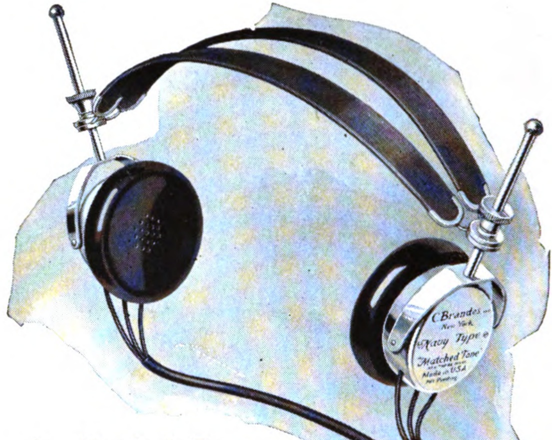
(See next page)

C. Brandes, Inc.

"Matched Tone" Headsets

TRADEMARK REG. U.S. PAT. OFF.

237 Lafayette St., New York



Brandes Matched Tone

Reg. U. S. Pat. Off.

NAVY TYPE HEADSETS

The Navy Type Brandes *Matched Tone* Headset represents the crowning achievement of fifteen years of successful radio experience. It is the standard of perfection in radio headsets.

Its extreme lightness, its radio-frequency shielded headset cord, and its unequalled clarity and harmony of tone make it the ideal headset for home use or most exacting laboratory work.

Impedance at 1000 cycles, approximately 25,000 ohms. Minimum current for audible signal at 1000 cycles, approximately 1.6x10 amperes.

LIST PRICE

Brandes Navy Type *Matched Tone* Headset with headband and radio-frequency cord $12.00

Distributors and Branch Offices:

76 Pearl Street, Boston, Mass.
Munsey Building, Washington, D. C.
331 Rialto Building, San Francisco, Cal.
302 Flatiron Building, Atlanta, Ga.
33 South Clinton Street, Chicago, Ill.
705 Granite Building, Pittsburgh, Pa.
1028 Fourth Avenue, Huntington, West Va.

Distributed in Canada by Perkins Electric, Limited
Toronto MONTREAL Winnipeg

Made in Canada and England by
Canadian Brandes, Limited, Toronto and London

Distributors in Australia and New Zealand
International Electric Co., Wellington, N. Z.

C.Brandes, INC.

"Matched Tone" Headsets

TRADEMARK REG. U.S. PAT. OFF.

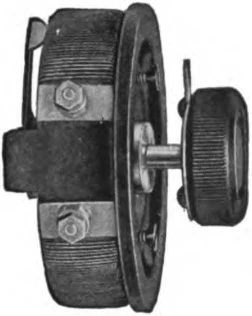
237 Lafayette St., New York

INSTRUMENTS USED BY

The Bureau of Standards and Other Leading Laboratories

For nearly a decade the General Radio Company has been manufacturing radio measuring instruments and standard radio parts that are used extensively in the radio laboratories of the Bureau of Standards. Signal Corps, Navy and other government departments, as well as in such nationally known laboratories as those of the General Electric Co., Westinghouse Electric & Mfg. Co., Western Electric Co., Radio Corp. of America and many others. Our measuring instruments, in particular, are used extensively in the laboratories of the country's leading educational institutions such as Harvard, Yale, Massachusetts Institute of Technology, Princeton and over one hundred other colleges.

Our instruments fall into two main groups; namely, measuring instruments, and standard radio parts. Because of the research work required for the development of the measuring instruments, we have much data that has been used in the development of our standard parts, which has made them far superior to the usual parts on the market. It is not possible to list all of these parts here and it is, accordingly, recommended that you send for FREE RADIO BULLETIN 914LA.



These parts which have become known as a standard of quality include the following:

Filament Rheostats
High Resistance Potentiometers
Vacuum Tube Sockets
Amplifying Transformers
Modulation Transformers
Inductance Coils
Hot-Wire Ammeters
Low Loss Condensers
Wavemeters
Porcelain Insulators
Switches and Sinclair Small Parts

GENERAL RADIO COMPANY

Manufacturers of

Electrical and Radio Laboratory Apparatus

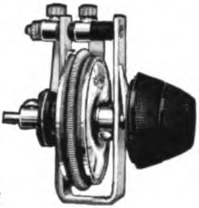
MASSACHUSETTS AVE. and WINDSOR ST.

CAMBRIDGE 39 **MASSACHUSETTS**

C-H Radio Rheostats Built By Rheostat Builders

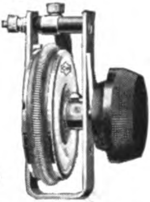
C-H 4 Ohm Vernier Rheostat

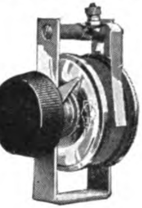
Perfect control for standard 6-volt detector tubes and dry cell (WD11) tubes. Built and guaranteed by the master builder of all rheostatic-control apparatus. Arranged for panel mounting and finished in satin nickel and ebony black. Packed complete with template.
Type 11601—H1..................$1.50



C-H 4 Ohm Radio Rheostat

Furnished without vernier adjustment—for amplifier control (using C-301 type, 5-volt. 1 amp., or WD11, dry-cell tubes). Large number of small turns of resistor gives accurate control, the nickeled pointer at all times indicating amount of resistance in circuit. Packed complete in unit box with template.
Type 11601—H2.....................$1.00



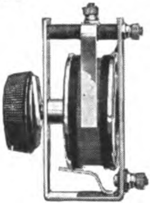


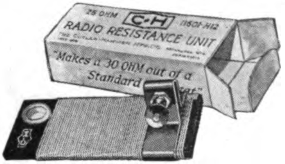
C-H 30 Ohm Radio Rheostat

For the control of amplifier tubes of the C-301-A type in which a current of only approximately ¼ amp. is required. Pointer indicating, and furnished (like all other C-H rheostats) with comfortable cone-shaped knobs of genuine Thermoplax. Packed complete with template for easy panel mounting, $1.50.

C-H Radio "A" Battery Potentiometer

For the accurate control of the plate potential for increased range and signal strength. Resistor cannot become displaced through constant usage and is subjected to minimum wear. Matches exactly in appearance and correctness of construction this precision line of radio control instruments *"built by current control specialists."*..............................$1.50





C-H Radio Resistance Unit

The C-H Radio Resistance Unit adds to your present rheostats just the number of ohms required for the regulation of the new ¼ ampere tubes. It can be attached to any rheostat already mounted, or directly on the panel..............$.25

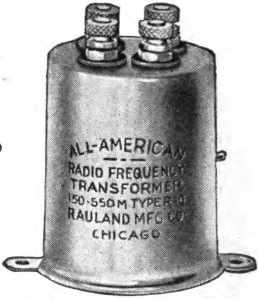
Over a Quarter Million C-H Rheostats Now in Use

CUTLER-HAMMER

Confidence

These leading manufacturers of quality radio sets:

Cutting & Washington
Jones Radio
Cleartone
Zenith (Chicago Radio Laboratory)
Midwest Radio Co.
Audiola Radio Co.
Illinois Radio Eng. Co.

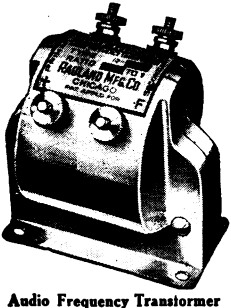


Radio Frequency Transformer
R-10 (150-550 meters) $4.50

and others — use

"ALL-AMERICAN" Amplifying Transformers

(*Radio and Audio Frequency*)



Audio Frequency Transformer
R-12 (Ratio 3 to 1) $4.50
R-21 (Ratio 5 to 1) 4.75
R-13 (Ratio 10 to 1) 4.75

as standard equipment in their sets. This is reason enough why any man building his own set should use "All-American" Transformers. The sales of these manufacturers depend on the efficiency of their apparatus. The confidence they place in "All-American" Transformers to function properly under all conditions is proof of the quality of these instruments. Buy them—use them—and you, too, will endorse them. Every live radio dealer carries them. To help you get the best results from your radio set we offer **FREE** a book of twenty-five tested hook-ups. Send 2c stamp for postage.

RAULAND MFG. CO.

200 No. Jefferson St., Chicago, Ill.

DALTON WHITTIER TRUE CO.
ESTRU
MANFRS. CHICAGO.

UNI-FLEX PARTS

Flexible Units

Compact—Efficient Interchangeable Inductance Units

Combinations made up for use in all standard circuits.

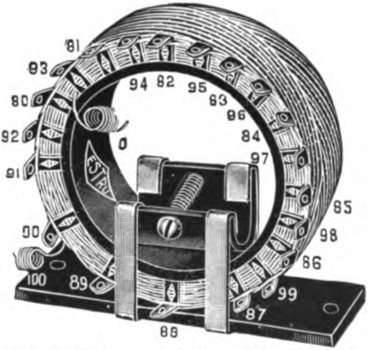
In the present state of the art it is impossible to construct coils having pure inductance values, due to the capacity or condenser effect between the turns of the wire which make up the inductances. This capacity depends upon the closeness of the turns and the characteristics of the dielectric or insulating material between conductors. All of these factors have been carefully considered, both in the design and manufacture of ESTRU Lattice Wound Products.

Estru Lattice Coils

Uni-Flex 100-T-22
For Use as Active Twenty in Kauffman Circuit
Unmounted ... $2.25
With Uni-Flex Mounting ... 3.00

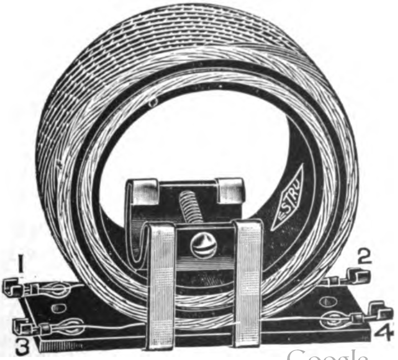
Uni-Flex 150-T-10
For Ultra Audion
Unmounted ... $2.00
With Uni-Flex Mounting ... 2.75

Uni-Flex Coil Mount
Fits any Size Coil
Plain .... $.85
With Solder Clips 1.10
With Nickel Plated Binding Posts 1.50



Inductances in All Standard Sizes—Plain or Mounted.

EFFICIENT DESIGN
SAVING OF SPACE
TESTED PRODUCTS
RESULTS THAT COUNT
UNI-FLEX PARTS



Uni-Flex R. F. Transformer

Turn Ratio 4 to 1.... $2.00
For use in Neutrodyne Circuit.
Use with Estru Micro-Mike Condenser..... $.75
Variable Capacity .7 to 2.0 M.M.F.
Uni-Flex Load Coil...... $2.00
Natural Wave-Length 50 to 100 or 150 Meters.

Estru Radio Products

At your Dealer or Write Us

Magnavox Products

THE MAGNAVOX line includes an ideal apparatus for every purpose of Radio reproduction and amplification. Where Radio equipment must meet the test of satisfying really discriminating people, Magnavox is certain to be installed.

MAGNAVOX RADIO

The Reproducer Supreme

Magnavox Reproducers are constructed on the famous Electro-Dynamic principle—the only principle by which a reproducer can meet the requirements of sound amplification according to its original pitch, quality and volume.

These instruments can be used with any receiving set of good quality: without the Magnavox no Radio set is complete.

R2 Magnavox Reproducer with 18-inch curvex horn: the utmost in amplifying power; for clubs, hotels, dance halls, large audiences, etc. Requires only .6 of an ampere for the field..........$60.00

R3 Magnavox Reproducer with 14-inch curvex horn in efficient acoustic finish (as illustrated): ideal for use in homes, offices, amateur stations, etc., ...$35.00

The horn supplied with Magnavox Reproducers is of spun copper, resisting accidental blows and deterioration through climatic changes.

R 3
with 14-inch horn

Magnavox Power Amplifiers

THESE are true *Power* Amplifiers, designed to give a *Power* output, and are free from elements of distortion. Any standard amplifying tube may be used.

Magnavox Power Amplifiers (in two sizes as listed below) are made to the highest standards of technical efficiency, convenience of operation and refinement of finish.

Model C 2-stage

AC-2-C with two stages of power amplification. For use with the Magnavox Reproducer, to insure getting largest possible power input. Switching from stage to stage is made easy by master switches. Bakelite panel. Highly finished hardwood case. Without tubes.............$55.00

AC-3-C: the same as the above instrument, but with three stages of power amplification, giving maximum volume. Without tubes........................$75.00

Magnavox Products can be had of good dealers everywhere. Ask for demonstration.

THE MAGNAVOX COMPANY

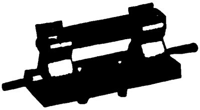
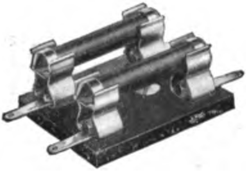
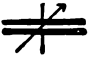
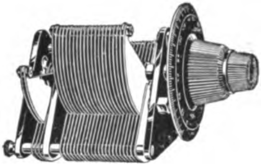
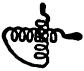
OAKLAND, CALIFORNIA

New York Office, 370 Seventh Ave.

KELLOGG SWITCHBOARD & SUPPLY COMPANY

Chicago, Illinois

SYMBOLS OF STANDARD EQUIPMENT

Symbol	Illustration	Description
 Fixed Condenser		Size 1 7/8"x 3/8". Capacities—.01—.006 .005—.0025—.001 —.0005—.00025 Mfd.
 Grid Condenser		Miniature condensers have the same capacities as the above fixed condensers.
 Variable Condenser		Decremeter Type 11-23 and 43 plate types with or without vernier. Standard capacities.
 Variometer		All Bakelite moulded variometer. Two rotor and three stator terminals. Standard wound. For panel or base mounting.
 Phone		2400 ohm per pair. Impedance and ampere turns at highest relative efficiency. Super sensitive. Lightest in weight; first to receive signals, last to choke on amplification.

RADION

The Supreme Insulation for Radio Panels and Parts

AMERICAN HARD RUBBER CO.

11 Mercer Street, New York City

The four most important characteristics of insulating material for radio use are *low phase angle difference, low dielectric constant, high resistivity and non-absorbent qualities.*

RADION excels in all the above. Comparisons with Phenolic and Laminated Phenolic Insulations are as follows:

	RADION	*Phenolic* and *Laminated Phenolic Materials*
Phase Angle Difference ...	0.5 to 0.6	2.0 to 3.7
Dielectric Constant	3.9	5.8 to 7.4
Resistivity (Megohms-cm)	1.0×10^8	1.4×10^4 to 2.2×10^6
Absorption of Moisture:		
In Air	0.005 to 0.02%	0.28% to 0.49%
In Water	0.08% to 0.11%	1.42% to 7.81%

Figures given in the above table for phase angle difference, dielectric constant and resistivity were reported by the Bureau of Standards. Absorption of moisture in air and in water were determined in our own laboratory.

These results prove that RADION surpasses all other materials in electrical insulating properties.

RADION is a special compound of hard rubber developed particularly for radio use and manufactured exclusively by the American Hard Rubber Company. It is non-porous, non-absorbent, warp resisting, absolutely permanent, may be easily moulded or accurately machined to gauge, drilled, cut, threaded, engraved, stamped, sanded and polished without danger of chipping.

RADION PANEL SHEETS

Radion panel sheets are made in two colors:—black and mahogany grained (called mahoganite). This latter material is the handsomest panel stock ever offered for radio use. The beautiful mahogany grain is obtained by a new special process. This material will enhance the appearance of any outfit, as it not only possesses the grained effect of genuine mahogany, but has a fine, satin-like surface polish, unusual among insulation materials.

Stock Sizes—Black and Mahoganite

Thickness	Size	Thickness	Size	Thickness	Size
3/16 ins.	6x 7 ins.	3/16 “	7x14 ins.	1/4 “	10x12 ins.
3/16 “	6x10½ “	3/16 “	7x18 “	3/16 “	12x14 “
3/16 “	6x14 “	3/16 “	7x21 “	3/16 “	12x21 “
3/16 “	6x21 “	3/16 “	7x24 “	3/16 “	14x18 “
3/16 “	7x 9 “	3/16 “	7x48 “	3/16 “	20x24 “
3/16 “	7x10 “	3/16 “	9x14 “	1/4 “	20x24 “
3/16 “	7x12 “	3/16 “	10x12 “		

Special Sizes—Special sizes are supplied in lots aggregating 50 or more square feet per size.

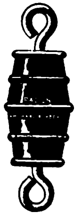
RADION PARTS

Variometer Rotors—No. .012B, supplied unwired and without metal parts as shown in figure, 2½″ wide by 3$^{11}/_{16}$″ in diameter.

Quotations on special moulded Variometer parts on request.

Dial

V-T Socket



Insulator

Radion Dials—Moulded in one piece with tapered knobs, graduated either clockwise or counter-clockwise. Made in standard sizes of 2¼, 3, 3¼ and 4 inches in diameter with metal insert and adapter bushing to fit either $^3/_{16}$ or ¼ inch shafts. Packed in individual boxes.

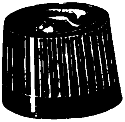
V-T Sockets—A Moulded Radion socket and base for standard detector and amplifier tubes. Supplied complete with metal contact pieces and binding posts. Packed in individual boxes.

Aerial Insulators, No. 1 Brown, 3½ in. overall—Unusually high dielectric strength and strain resistance. Galvanized eyelets are strongly imbedded.

Standard Rods and Tubing—A large range of sizes of unpolished rods and tubing are carried in stock in standard 24″ lengths; prices on application.

Variometer Tubing—Supplied unpolished as shown

No.	Outside Diam.	Wall Thickness	Length
1	4″	⅛″	3″
2	4″	⅛″	3½″
3	4″	⅛″	4″
4	4″	⅛″	5″
5	2″	⅛″	30″
6	2½″	⅛″	30″
7	3″	⅛″	30″
8	3½″	⅛″	30″
9	4″	⅛″	30″



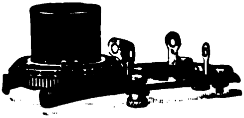
6233

Radion Knobs—Knobs No. 6233 are regularly supplied with set screws and drilled to fit shafts as ordered.

RADION Panels and parts are stocked by dealers in radio and electrical supplies.

AMERICAN HARD RUBBER CO.

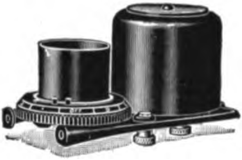
11 Mercer St., New York City



Detector Unit

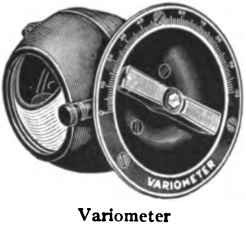
The outstanding feature of Eisemann Radio Units, aside from their uniform excellence, is ease of assembly.

The panels, illustrated on the following page, are completely drilled and the Units are fastened with screws and nuts. The only tool required is a small screw-driver.



Amplifier Unit

Condenser



Variometer

Complete descriptive catalog mailed free upon request

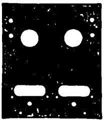
Variocoupler

METAL PANELS

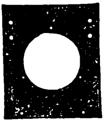
Aluminum panels in several sizes are offered for use with Eisemann Radio Units.

Uniform size openings permit interchangeable mounting.

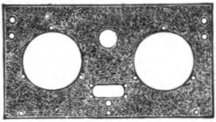
The metal panel, itself, acts as an ideal capacity shield; its use being made possible by the complete self-insulation of all Eisemann Units.



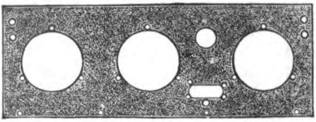
Type A-2



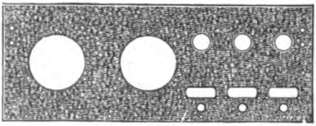
T-1



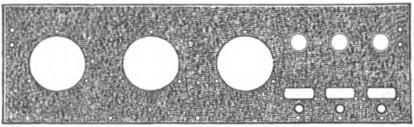
TD-2



TD-3



TD-2A



TD-3A

For sale by progressive dealers everywhere

EISEMANN MAGNETO CORPORATION

William N. Shaw, President

Brooklyn, N. Y.

Detroit **Chicago** **San Francisco**

CHAPTER EIGHT

UNDERWRITERS' REGULATIONS

March 12, 1923

Note:—These rules do not apply to Radio Equipment installed on shipboard.

In setting up Radio Equipment all Wiring Pertaining thereto must conform to the General Requirements of the National Electrical Code for the class of work installed and the following Additional Specifications:

FOR RECEIVING STATIONS ONLY

(Sections a to d, inclusive, do not apply when antenna is installed inside of buildings.)

ANTENNA:

a. Antenna and counterpoise outside of buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be located and provided with suitable clearances, so as to prevent accidental contact with such wires by sagging or swinging.

Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

Light and power circuits, if used for receiving antenna, need not conform to any of the above requirements, but the devices used to connect the light and power conductors to radio receiving sets must be of an approved type.

LEAD-IN-CONDUCTORS:

b. Lead-in-conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14 B. & S. gauge except that bronze or copper-clad steel not less than No. 17 B. & S. gauge may be used.

Lead-in-conductor on the outside of buildings shall not come nearer than four (4) inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor that will maintain permanent separation. The non-conductor shall be in addition to any insulation on the wire.

Lead-in-conductor shall enter building through a non-combustible, non-absorptive insulating bushing slanting upward toward the inside.

PROTECTIVE DEVICE:

c. Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of five hundred (500) volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground (see section **d**), or outside the building as near as practicable to the point of entrance. **The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.**

The use of an antenna grounding switch is desirable, but does not obviate the necessity for the approved protective device required under this section. The antenna grounding switch if installed shall, in its closed position, form a shunt around the protective device.

A knife switch not less than 30 amp., 250 volts, is recommended to be located between lead-in conductor and receiving set.

Fuses are not required, but if used shall not be placed in the circuit from the antenna through the protective device to ground.

PROTECTIVE GROUNDING CONDUCTOR:

d. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The grounding conductor shall not be smaller than the lead-in conductor, and in no case shall be smaller than No. 14 B. & S. gauge if of copper, nor smaller than No. 17 B. & S. gauge if of bronze or copper-clad steel. The grounding conductor shall be run in as straight a line as possible from the protective device to a good, permanent ground. **Preference shall be given to water piping.** Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds such as driven pipes, rods, plates, cones, etc. **Gas piping shall not be used for the ground.**

The grounding conductor shall be protected where exposed to mechanical injury. An approved ground clamp shall be used where the grounding conductor is connected to pipes or piping.

RECEIVING EQUIPMENT GROUNDING CONDUCTOR:

e. The grounding conductor may be run either inside or outside of the building. The protective grounding conductor and ground installed as specified in Section d may be used as the operating ground. In this case the operating grounding conductor should preferably be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, the grounding conductor being bare or with an insulating covering.

WIRES INSIDE BUILDINGS:

f. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than two (2) inches to any electric light or power wire not in conduit, unless separated therefrom by some continuous and firmly fixed non-conductor making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire. Porcelain tubing or approved flexible tubing may be used for encasing wires to comply with this rule.

Storage battery leads shall consist of conductors having approved rubber insulation. It is recommended that the circuit from the storage battery be properly protected by fuses located as near as possible to the battery.

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION ACCORDING TO THE INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

	Question	Answer or Notice
QRA	What ship or coast station is that?	This is......
QRB	What is your distance?..........	My distance is......
QRC	What is your true bearing?......	My true bearing is......degrees
QRD	Where are you bound for?.......	I am bound for......
QRF	Where are you bound from?.....	I am bound from.......
QRG	What line do you belong to?.....	I belong to the......Line
QRH	What is your wave length?......	My wave length is......meters
QRJ	How many words have you to send?	I have......words to send
QRK	How do you receive me?.........	I am receiving well
QRL	Are you receiving badly? Shall I send 20?..................... . . . . — . for adjustment.	I am receiving badly. Please send 20? . . . . — . for adjustment
QRLL	Request permission to test min's	Permission to test granted
QRM	Are you being interfered with?...	I am being interfered with
QRN	Are the atmospherics strong?.....	Atmospherics are very strong
QRO	Shall I increase power?..........	Increase power
QRP	Shall I decrease power?.........	Decrease power
QRQ	Shall I send faster?............	Send faster
QRS	Shall I send slower?............	Send slower
QRT	Shall I stop sending?...........	Stop sending
QRU	Have you anything for me?......	I have nothing for you
QRV	Are you ready?.................	I am ready. All right now
QRW	Are you busy?..................	I am busy (or: I am busy with...). Please do not interfere
QRX	Shall I stand by?.	Stand by. Will call when required
QRY	When will be my turn?..........	Your turn will be No.......
QRZ	Are my signals weak?...........	Your signals are weak
QSA	Are my signals strong?..........	Your signals are strong
QSB	Is my tone bad?.............. Is my spark bad?.............	The tone is bad The spark is bad
QSC	Is my spacing bad?.............	Your spacing is bad
QSD	What is your time?...........	My time is. . ...
QSF	Is transmission to be in alternate order or in series?.........	Transmission will be in alternate order. QSG will be in series of 5 messages. QSH will be in series of 10 messages
QSJ	What rate shall I collect for......?	Collect......
QSK	Is the last radiogram canceled?...	The last radiogram is canceled
QSL	Did you get my receipt?.........	Please acknowledge
QSM	What is your true course?.......	My true course is......degrees
QSN	Are you in communication with land?.....................	I am not in communication with land
QSO	Are you in communication with any ship or station (or: with...)?	I am in communication with..... (through......)
QSP	Shall I inform......that you are calling him?.................	Inform......that I am calling him
QSQ	Is.. . .calling me?............	You are being called by......
QSR	Will you forward the radiogram?	I will forward the radiogram
QST	Have you received the general call?	General call to all stations
QSU	Please call me when you have finished (or: at..o'clock)...........	Will call when I have finished
*QSV	Is public correspondence being handled?...................	Public correspondence is being handled. Please do not interfere
QSW	Shall I increase spark frequency?	Increase your spark frequency
QSX	Shall I decrease spark frequency?	Decrease your spark frequency
QSY	Shall I send on a wave length of ......meters?...............	Let us change to the wave length of......meters
QSZ	....	Send each word twice. I have difficulty in receiving you
QTA	....	Repeat the last radiogram
QTC	Have you anything to transmit?	I have something to transmit
QTE	What is my true bearing?	Your bearing is..degrees from...
QTF	What is my position?	Your position is..........latitude ....longitude

*Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

INTERNATIONAL MORSE CODE

For the convenience of those who may desire to master the reading of radio telegraph messages the International Morse Code is here given. This is the code used by all radio telegraph stations and is entirely distinct from that used on the wire telegraph. The latter is called the American Morse Code.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

A dash is equal in length to three dots.

The space between parts of the same letter is equal to one dot.

The space between two letters is equal in length to three dots.

The space between two words is equal in length to five dots.

CHARACTERISTICS OF RECEIVING AND POWER TUBES

The following table and the accompanying diagrams will be of great use in the selection of electron tubes and in their proper connection in receiving circuits when used as detectors and when used as amplifiers.

Receiving Tubes

Type	Filament		Plate		Amplification Factor	Output Resistance Ohms	Mutual Conductance Micromhos
	Volts "A"	Amperes	Volts "B"	Amperes			
*UV-199	3.0	0.06	40	0.001	6	....	....
UV-200	5.0	1.0	20	0.001·	....	....	....
UV-201	5.0	1.0	40	0.001	6	20,000	300
UV-201A	5.0	0.25	40	0.0012	6.8	16,000	425
*WD-11	1.1	0.25	45	0.0005	6	20,000	300
WD-12	1.1	0.25	45	0.0005	6	20,000	300
*French	3.8	0.70	40	....	7	30,000	230
DV-6A	2.7	0.3	22-45	....	6.5	25,000	260
*215A, N	1.1	0.25	45	0.0006	6.5	25,000	260
216A	6	1.0	120	0.008	6	6,000	1000
VT1, 203B	2.5	1.1	30	0.001	7.5	15,000	430
†*VT2, 205B	7	1.35	350	0.04	7	4,000	1750

Power Tubes

Type	Filament		Plate		Amplification Factor	Output Watts
	Volts "A"	Amperes	Volts "B"	Amperes		
UV-202	7.5	2.35	350	0.050	7.5	5
UV-203	10.0	6.50	1000	0.150	15.0	50
UV-203A	10.0	3.25	1000	0.125	25.	50
UV-204	11.0	14.75	2000	0.250	20.	250
UV-204A	11.0	3.85	2000	0.200	25.	250
UV-206	11.0	14.75	10000	0.125	250.	1000
UV-207	22.0	52.00	15000	1.800	40.	20000
UV-208	22.0	24.50	15000	0.450	300.	5000

*Special base. All other receiving tubes in this list fit the standard base.

†May be used also as a transmitting tube.

Most of the information in the above table is taken from material supplied by the manufacturers of the tubes. While individual tubes differ somewhat in their characteristics, the figures here given are believed to be fairly typical of tubes of these types.

The mutual conductance of an electron tube is the amplification factor divided by the output resistance. It is a better criterion of the effectiveness of the tube than either of its constituent factors alone.

Most of the receiving tubes now on the market may be used either as amplifiers or as detectors. The return connection from the grid circuit to the filament battery should be different in the two cases. When used as a detector, the grid circuit should be connected to the positive end of the filament, as shown in Fig. 1. When used as an amplifier, the grid circuit should be connected to the negative terminal of the filament battery with

the filament rheostat connected between this point and the negative terminal of the filament, as shown in Fig. 2.

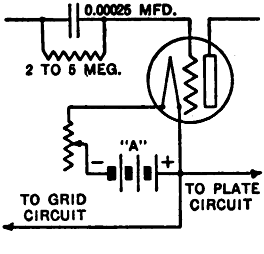


FIG. 1

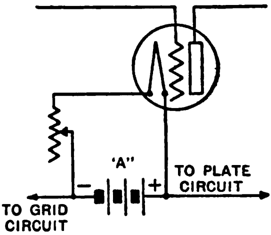


FIG. 2

If a higher voltage is used in the plate circuit of an amplifier tube than that given in column 4 of the above table, it is desirable to use an additional voltage or "C" battery in the grid circuit. About one volt of "C" battery should be used for each ten or fifteen volts increase in "B" battery above that given. Not more than 100 volts "B" battery nor 6 volts "C" battery should ordinarily be used. The "C" battery (sometimes called the grid bias battery) should have its negative terminal connected to the grid circuit and its positive terminal connected to the negative terminal of the filament "A" battery, as shown in Fig. 3. If a potentiometer is used as a method of controlling this grid bias, the connections should be made as shown in Fig. 4.

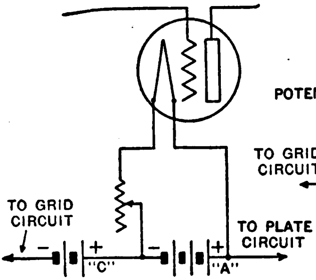


FIG. 3

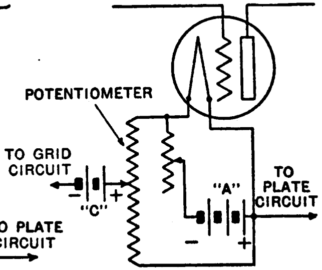


FIG. 4

Sometimes the application of an excessive filament or plate voltage causes a tube to become inoperative without actually burning out the filament. It can in some cases be restored by lighting the filament at the rated voltage for ten to twenty minutes with the plate or "B" battery entirely disconnected.

LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Completed to February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse E. & M. Co.	East Pittsburgh, Pa.	920	326	1000
KDPM	Westinghouse E. & M. Co.	Cleveland, Ohio....	1110	270	500
KDPT	Southern Electrical Co....	San Diego, Calif....	1230	244	100
KDYL	Salt Lake Telegram.......	Salt Lake City, Utah	833	360	100
KDYM	Savoy Theatre..........	San Diego, Calif....	1070	280	50
KDYQ	Oregon Inst. of Technology	Portland, Ore......	833	360	100
KDYW	Smith, Hughes & Co......	Phoenix, Ariz.......	833	360	10
KDYX	Star Bulletin Pub. Co....	Honolulu, Hawaii...	833	360	100
KDZB	Frank E. Siefert.........	Bakersfield, Calif...	1250	240	100
KDZE*	The Rhodes Co..........	Seattle, Wash......	1110	270	100
KDZF	Auto. Club of So. Calif.....	Los Angeles, Calif...	1080	278	500
KDZI	Electric Supply Co.......	Wenatchee, Wash..	833	360	50
KDZQ	Nichols Academy of Danc'g	Denver, Colo.......	833	360	10
KDZR	Bellingham Publishing Co.	Bellingham, Wash..	1150	261	50
KFAD	McArthur Bros. Co.......	Phoenix, Ariz......	833	360	100
KFAE	State College of Wash.....	Pullman, Wash.....	910	330	500
KFAF	Western Radio Corp......	Denver, Colo......	833	360	500
KFAJ	University of Colorado....	Boulder, Colo......	833	360	100
KFAN	The Electric Shop........	Moscow, Idaho.....	833	360	50
KFAR	Studio Lighting Service Co.	Hollywood, Calif...	1070	280	150
KFAU	Boise High School........	Boise, Idaho.......	1110	270	150
KFAW	The Radio Den..........	Santa Ana, Calif...	1070	280	10
KFAY	W. J. Virgin............	Medford, Ore......	1060	283	50
KFBB	F. A. Buttrey & Co.......	Havre, Mont.......	833	360	100
KFBC	W. K. Azbill............	San Diego, Calif....	1080	278	10
KFBE	Reuben H. Horn.........	San Luis Obispo, Cal.	833	360	10
KFBG	First Presbyterian Church.	Tacoma, Wash.....	833	360	50
KFBK	Kimball-Upson Co........	Sacramento, Calif...	1060	283	100
KFBL	Leese Bros..............	Everett, Wash.....	1340	224	10
KFBS	Trinidad Gas & Electric Supply Co. & Chronicle News Publishing Co....	Trinidad, Colo.....	833	360	15
KFBU	Bishop N. S. Thomas.....	Laramie, Wyo......	1060	283	50
KFCB	Nielson Radio Supply Co..	Phoenix, Ariz......	1080	278	10
KFCF	Frank A. Moore..........	Walla Walla, Wash.	833	360	100
KFCH	Elec. Service Station, Inc..	Billings, Mont.....	833	360	10
KFCM	Richmond Radio Shop....	Richmond, Calif....	833	360	100
KFCP	Ralph W. Flygare........	Ogden, Utah.......	833	360	25
KFCV	Fred Mahaffey, Jr........	Houston, Tex......	833	360	10
KFCY	Western Union College....	Le Mars, Iowa.....	1190	252	50
KFCZ	Omaha Central H. S.......	Omaha, Nebr......	1160	259	100
KFDA	Adler's Music Store.......	Baker, Ore........	833	360	5
KFDD	St. Michael Cathedral.....	Boise, Idaho.......	1190	252	10
KFDH	University of Arizona.....	Tucson, Ariz.......	833	360	150
KFDJ	Oregon Agri. College......	Corvallis, Ore......	833	360	50
KFDL	Knight-Campbell Mus. Co.	Denver, Colo......	833	360	5
KFDO	H. E. Cutting...........	Bozeman, Mont....	1210	248	50
KFDR	Bullock's Hardware Co....	York, Nebr........	833	360	10
KFDV	Gilbrech & Stinson.......	Fayetteville, Ark...	833	360	10
KFDX	First Baptist Church......	Shreveport, La.....	833	360	100
KFDY	S. Dak. State College.....	Brookings, S. Dak..	833	360	100
KFDZ	Harry O. Iverson.........	Minneapolis, Minn..	1300	231	5
KFEC	Meier & Frank Co........	Portland, Ore......	1210	248	50
KFEJ	Guy Greason............	Tacoma, Wash.....	833	360	10
KFEL	Winner Radio Corp.......	Denver, Colo......	833	360	150
KFEQ	J. L. Scroggin...........	Oak, Nebr........	833	360	150
KFER	Auto. Elec. Service Co.....	Fort Dodge, Iowa..	1300	231	10
KFEV	Felix-Thompson Radio Shop	Casper, Wyo.......	1140	263	250
KFEX	Augsburg Seminary.......	Minneapolis, Minn..	1150	261	100
KFEY	Bunker Hill & Sullivan Mining & Concentr. Co	Kellogg, Idaho.....	833	360	10

*This Company also operates station KFOA

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
KFEZ	Am. Soc. Mech. Engrs....	St. Louis, Mo......	833	360	250
KFFB	Jenkins Furniture Co.....	Boise, Idaho........	1250	240	10
KFFE	Eastern Oregon Radio Co..	Pendleton, Ore.....	833	360	10
KFFO	Dr. E. H. Smith..........	Hillsboro, Ore......	1310	229	5
KFFQ	Marksheffel Motor Co....	Colo. Springs, Colo..	1160	259	10
KFFR	Nevada State Journal	Sparks, Nev........	1330	225	10
KFFV	Graceland College.........	Lamoni, Iowa......	833	360	100
KFFX	The McGraw Co..........	Omaha, Nebr......	1080	278	100
KFFY	Pincus & Murphey, Inc...	Alexandria, La.....	1090	275	100
KFFZ	A. G. Barnes Amus. Co...	Dallas,Tex.,Portable	1330	225	20
KFGC	Louisiana State Univ.....	Baton Rouge, La...	1180	254	100
KFGD	Chickasha Rad. & Elec. Co.	Chickasha, Okla....	1210	248	200
KFGH	Leland Stanford University	Stanford Univ.,Calif.	833	360	500
KFGJ	Nat. Guards Missouri, 138th Infantry.........	St. Louis, Mo......	1130	265	100
KFGL	Arlington Garage..........	Arlington, Ore.....	1280	234	5
KFGQ	Crary Hardware Co.......	Boone, Iowa.......	1330	225	10
KFGV	Heidbreder Radio Sup. Co.	Utica, Nebr........	1340	224	10
KFGX	First Presbyterian Church.	Orange, Tex........	1200	250	500
KFGZ	Emmanuel Missionary Col.	Berrien Sprgs.,Mich.	1120	268	250
KFHA	Western State Col. of Colo.	Gunnison, Colo.....	1190	252	50
KFHB	P. L. Boardwell..........	Hood River, Ore...	1070	280	5
KFHD	Utz Electric Co..........	St. Joseph, Mo.....	1330	225	100
KFHF	Central Christian Church..	Shreveport, La.....	1130	265	150
KFHH	A. A. McCue............	Neah Bay, Wash...	1150	261	50
KFHJ	Fallon & Company.......	Santa Barbara, Calif.	833	360	100
KFHR	Star Elec. & Radio Co....	Seattle, Wash......	1060	283	50
KFHS	Clifford J. Dow..........	Lihue, Hawaii......	1090	275	30
KFHX	Robert W. Nelson........	Hutchinson, Kans..	1310	229	150
KFI	Earle C. Anthony (Inc.)...	Los Angeles, Calif..	640	469	500
KFID	Ross Arbuckle...........	Iola, Kans.........	1220	246	20
KFIF	Benson Polytechnic School	Portland, Ore......	833	360	100
KFIL	Windisch El. Farm Eq. Co.	Louisburg, Kans....	1280	234	30
KFIO	North Central H. S.......	Spokane, Wash.....	1190	252	50
KFIQ	Yakima Valley Radio Broadcasting Assn......	Yakima, Wash.....	1240	242	50
KFIU	Alaska Elec. Light & Power Co..................	Juneau, Alaska.....	1330	225	10
KFIX	Reorganized Church of Jesus Christ of Latter Day Saints...............	Independence, Mo..	1250	240	250
KFIZ	Daily Commonwealth—O. A. Huelsman...........	Fond du Lac, Wis..	1100	273	100
KFJB	Marshall Elec. Co........	Marshalltown, Iowa	1210	248	10
KFJC	Seattle Post-Intelligencer..	Seattle, Wash......	1110	270	100
KFJF	Nation Radio Mfg. Co....	OklahomaCity,Okla.	1190	252	20
KFJI	Liberty Theatre — E. E. Marsh...............	Astoria, Ore.......	1190	252	10
KFJK	Delano Radio & Elec. Co...	Bristow, Okla......	1280	234	100
KFJL	Hardsace Mfg. Co........	Ottumwa, Iowa....	1240	242	10
KFJM	Univ. of North Dakota....	Grand Forks, N. D..	1070	280	100
KFJQ	Valley Radio Div. of Elec. Constr. Co...........	Grand Forks, N. D. (Portable).......	1070	280	5
KFJR	Ashley C. Dixon & Son....	Stevensville, Mont..	1160	259	50
KFJV	Thomas H. Warren.......	Dexter, Iowa.......	1340	224	10
KFJW	Legrand Radio Co.........	Towanda, Kans....	1330	225	10
KFJX	Iowa State Teachers Col...	Cedar Falls, Iowa...	1310	229	50
KFJY	Tunwall Radio Co........	Ft. Dodge, Iowa....	1220	246	50
KFJZ	Texas National Guard 112th Cavalry.........	Ft. Worth, Texas...	1180	254	20
KFKA	Colo. State Teachers Col..	Greeley, Colo......	1100	273	50
KFKB	Brinkley-Jones Hospital Assn................	Milford, Kansas....	1050	286	500
KFKQ	Conway Radio Labs......	Conway, Ark.......	1340	250	100
KFKV	F. F. Gray..............	Butte, Mont........	1060	283	50

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFKX	Westinghouse E. & M. Co.	Hastings, Nebr.....	880	341	1000
KFKZ	Nassour Bros. Radio Co...	Colorado Sprgs, Colo.	1280	234	10
KFLA	Abner R. Willson.........	Butte, Mont.......	1060	283	5
KFLB	Signal Electric Mfg. Co...	Menominee, Mich..	1210	248	5
KFLD	Paul E. Greenlaw.........	Franklinton, La....	1280	234	20
KFLE	National Educ. Service....	Denver, Colo......	1120	268	25
KFLH	Erickson Radio Co., Inc...	Salt Lake City, Utah	1150	261	50
KFLP	Everetts M. Foster........	Cedar Rapids, Iowa	1250	240	20
KFLQ	Bissell Radio Shop........	Little Rock, Ark...	1150	261	20
KFLR	Univ. of New Mexico.....	Albuquerque, N.Mex	1180	254	100
KFLU	Rio Grande Radio Supply House................	San Benito, Texas..	1270	236	20
KFLV	Rev. A. T. Frykman......	Rockford, Ill.......	1310	229	100
KFLW	Missoula Elec. Supply Co..	Missoula, Mont....	1280	234	10
KFLX	George Roy Clough........	Galveston, Texas...	1250	240	10
KFLY	Fargo Radio Supply Co...	Fargo, N. D........	1300	231	20
KFLZ	Atlantic Automobile Co...	Atlantic, Iowa.....	1100	273	10
KFMB	Christian Churches of Little Rock..................	Little Rock, Ark....	1180	254	50
KFMQ	Univ. of Arkansas.........	Fayetteville, Ark...	1140	263	100
KFMR	Morningside College......	Sioux City, Iowa...	1150	261	10
KFMS	Freimuth Dept. Store.....	Duluth, Minn......	1090	275	100
KFMT	Dr. Geo. W. Young.......	Minneapolis, Minn..	1300	231	5
KFMU	Stevens Bros.............	San Marcos, Texas..	1250	240	20
KFMW	M. G. Sateren...........	Houghton, Mich....	1130	265	50
KFMX	Carleton College..........	Northfield, Minn...	1060	283	500
KFMY	Boy Scouts of America, Long Beach Dist. Council	Long Beach, Calif..	1310	229	20
KFMZ	Roswell Broadcasting Club	Roswell, N. M.....	1200	250	100
KFNC	Alonzo Monk, Jr..........	Corsicana, Tex.....	1280	234	20
KFNF	Henry Field Seed Co.....	Shenandoah, Iowa..	1130	266	500
KFNG	Wooten's Radio Shop.....	Coldwater, Miss. ...	1180	254	10
KFNH	State Teachers College....	Springfield, Mo. ...	1270	236	20
KFNJ	Warrensburg Elec. Shop..	Warrensburg, Mo...	1280	234	50
KFNL	Radio Broadcast Ass'n....	Paso Robles, Calif..	1250	240	10
KFNV	L. A. Drake Battery & Radio Supply Shop.....	Santa Rosa, Calif...	1280	234	5
KFNX	Peabody Radio Service ...	Peabody, Kansas...	1250	240	10
KFNY	Montana Phonograph Co..	Helena, Mont......	1150	261	5
KFNZ	Royal Radio Company....	Burlingame, Calif...	1300	231	10
KFOA*	The Rhodes Co..........	Seattle, Wash......	660	454	500
KFSG	Echo Park Evangelistic Ass'n................	Los Angeles, Calif..	1280	234	500
KGB	Tacoma Daily Ledger.....	Tacoma, Wash.....	1190	252	50
KGG	Hallock & Watson Radio Service................	Portland, Ore......	833	360	50
KGN	Northwestern Rad.Mfg.Co.	Portland, Ore......	833	360	15
KGO	General Elec. Co.........	Oakland, Calif.....	960	312	1000
KGU	Marion A. Mulrony.......	Honolulu, Hawaii...	833	360	250
KGW	Oregonian Publishing Co..	Portland, Ore......	610	492	500
KGY	St. Martins College.......	Lacey, Wash.......	1160	259	5
KHJ	Times-Mirror Co..........	Los Angeles, Cal...	760	395	500
KHQ	Louis Wasmer...........	Seattle, Wash......	833	360	100
KJQ	C. O. Gould	Stockton, Calif.....	833	360	5
KJR	Northwest Radio Serv. Co.	Seattle, Wash......	1060	283	50
KJS	Bible Inst. of Los Angeles..	Los Angeles, Calif..	833	360	750
KLS	Warner Bros.............	Oakland, Calif.....	833	360	250
KLX	Tribune Publishing Co....	Oakland, Calif.....	590	508	500
KLZ	Reynolds Radio Co., Inc..	Denver, Colo......	833	360	500
KMJ	San Joaquin Lt. & P'r Corp.	Fresno, Calif.......	1210	248	50
KMO	Love Electric Co.........	Tacoma, Wash.....	833	360	10
KNT	Gray's Harbor Radio Co..	Aberdeen, Wash....	1140	263	250
KNV	Radio Supply Co.........	Los Angeles, Calif..	1180	254	100

*This Company also operates station KDZE

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KNX	Elec. Light Supply Co.	Los Angeles, Calif.	833	360	100
KOB	N. Mex. College of Agriculture and Mechanic Arts	State College, N. Mex	833	360	500
KOP	Detroit Police Dept.	Detroit, Mich.	1050	286	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	710	422	500
KQP	Apple City Radio Club	Hood River, Ore.	833	360	10
KQV	Doubleday-Hill Electric Co.	Pittsburgh, Pa.	1070	280	500
KQW	Charles D. Herrold	San Jose, Calif.	833	360	50
KRE	Berkeley Daily Gazette	Berkeley, Calif.	1090	275	50
KSD	Post-Dispatch	St. Louis, Mo.	550	545	500
KSS	Prest & Dean Radio Elec. Co.	Long Beach, Calif.	1310	229	10
KTW	First Presbyterian Church	Seattle, Wash.	833	360	750
KUO	Examiner Printing Co.	San Francisco, Calif.	833	360	150
KUS	City Dye Works & Laundry Co.	Los Angeles, Calif.	833	360	100
KUY	Coast Radio Co., Inc.	El Monte, Calif.	1170	256	50
KWG	Portable Wireless Telephone Co.	Stockton, Calif.	833	360	100
KWH	Los Angeles Examiner	Los Angeles, Calif.	833	360	500
KXD	Herald Publishing Co.	Modesto, Calif.	1190	252	10
KYQ	Electric Shop	Honolulu, Hawaii	1040	288	100
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	560	535	1000
KZM	Preston D. Allen	Oakland, Calif.	833	360	100
KZN	Deseret News Publishing Co.	Salt Lake City, Utah	833	360	500
KZV	Wenatchee Battery & Motor Co.	Wenatchee, Wash.	833	360	50
WAAB	Valdemar Jensen	New Orleans, La.	1120	268	100
WAAC	Tulane University	New Orleans, La.	833	360	100
WAAD	Ohio Mechanics Institute	Cincinnati, Ohio	833	360	25
WAAF	Chicago Daily Drovers Journal	Chicago, Ill.	1050	286	200
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAN	University of Missouri	Columbia, Mo.	1180	254	50
WAAW	Omaha Grain Exchange	Omaha, Nebr.	833	360	500
WABA	Lake Forest College	Lake Forest, Ill.	1130	265	100
WABB	Dr. John B. Lawrence	Harrisburg, Pa.	1130	265	10
WABD	Parker High School	Dayton, Ohio	1060	283	10
WABE	Y. M. C. A.	Washington, D. C.	1060	283	100
WABG	Arnold Edwards Piano Co.	Jacksonville, Fla.	1090	275	10
WABH	Lake Shore Tire Co.	Sandusky, Ohio	1250	240	20
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	100
WABK	First Baptist Church	Worcester, Mass.	1190	252	10
WABL	Connecticut Agri. College	Storrs, Conn.	1060	283	100
WABM	F. E. Doherty	Saginaw, Mich.	1180	254	100
WABN	Ott Radio, Inc.	La Crosse, Wis.	1230	244	250
WABO	Lake Ave. Baptist Church	Rochester, N. Y.	1190	252	10
WABP	Robert Frederick Weinig	Dover, Ohio	1130	265	100
WABQ	Haverford College Radio Club	Haverford, Penna.	1150	261	50
WABR	Scott High School (J. W. B. Foley)	Toledo, Ohio	1110	270	50
WABS	Essex Mfg. Co.	Newark, N. J.	1230	244	50
WABT	Holliday-Hall, Radio Engrs.	Washington, Penna.	1190	252	100
WABU	Victor Talking Machine Co.	Camden, N. J.	1330	225	100
WABV	John H. DeWitt, Jr.	Nashville, Tenn.	1140	263	20
WABW	The College of Wooster, Physics Dept.	Wooster, Ohio	1280	234	20
WABX	Henry B. Joy	(near) Mt. Clemens, Mich.	1110	270	150
WABY	John Magaldi, Jr.	Philadelphia, Pa.	1240	242	50
WABZ	Coliseum Place Baptist Church	New Orleans, La.	1140	263	50
WBAA	Purdue University	West Lafayette, Ind.	833	360	250
WBAD	Sterling Electric Co.	Minneapolis, Minn.	833	360	100

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WBAH	The Dayton Co	Minneapolis, Minn.	720	416	500
WBAK	Penn. State Dept. of Police	Harrisburg, Pa.	750	400	500
WBAN	Wireless Phone Corp	Paterson, N. J.	1230	244	100
WBAO	James Millikin University	Decatur, Ill.	833	360	50
WBAP	The Ft. Worth Star Telegram	Fort Worth, Tex.	630	476	750
WBAV	Erner & Hopkins Co	Columbus, Ohio	770	389	500
WBAX	John H. Stenger, Jr.	Wilkes-Barre, Pa.	833	360	20
WBAY	Western Elec. Co	New York City, N.Y.	610	492	500
WBBA	Newark Radio Lab	Newark, Ohio	1250	240	20
WBBD	Barbey Battery Service	Reading, Pa.	1260	238	10
WBBE	Alfred R. Marcey	Syracuse, N. Y.	1220	246	10
WBBF	Georgia School of Technology	Atlanta, Ga.	1110	270	500
WBBG	Irving Vermilya	Mattapoisett, Mass.	1250	240	100
WBBH	J. Irving Bell	Port Huron, Mich.	1220	246	50
WBBI	The Indianapolis Radio Club	Indianapolis, Ind.	1280	234	20
WBBJ	Neel Elec. Co. (P. E. Neel)	W. Palm Beach, Fla.	1160	258	50
WBBK*	Kaufman & Baer Co	Pittsburgh, Pa.	1180	254	10
WBBL	Grace Covenant Church	Richmond, Va.	1060	283	10
WBBM	Frank Atlass Produce Co.	Lincoln, Ill.	1330	225	200
WBBN	A. B. Blake	Wilmington, N. C.	1090	275	10
WBBO	Michigan Limestone & Chem. Co	Rodgers, Mich.	1200	250	500
WBBP	Petoskey High School	Petoskey, Mich.	1220	246	10
WBBQ	Frank Crook	Pawtucket, R. I.	1190	252	100
WBBR	Peoples Pulpit Ass'n.	Rossville, N. Y.	1230	244	500
WBBS	First Baptist Church	New Orleans, La.	1200	250	50
WBBT	Lloyd Bros	Philadelphia, Pa.	1280	234	5
WBBU	Jenks Motor Sales Co	Monmouth, Ill.	1340	224	10
WBBV	Johnstown Radio Co	Johnstown, Pa.	1210	248	5
WBBW	Huffner Junior H. S	Norfolk, Va.	1350	222	50
WBL	T. & H. Radio Co	Anthony, Kans.	1150	261	100
WBR	Penna. State Police	Butler, Penna.	1050	286	250
WBS	D. W. May (Inc.)	Newark, N. J.	833	360	10
WBT	Southern Radio Corp	Charlotte, N. C.	833	360	500
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	890	337	1000
WCAD	St. Lawrence University	Canton, N. Y.	1070	280	250
WCAE*	Kaufman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCAG	Clyde R. Randall	New Orleans, La.	1120	268	50
WCAH	Entrekin Electric Co	Columbus, Ohio	1050	286	100
WCAJ	Nebraska Wesleyan Univ.	Univ. Place, Nebr.	833	360	500
WCAK	Alfred P. Daniel	Houston, Texas	1140	263	10
WCAL	St. Olaf College, Physics Dept	Northfield, Minn.	833	360	500
WCAM	Villanova College	Villanova, Pa.	833	360	150
WCAO	Sanders & Stayman Co.	Baltimore, Md.	833	360	50
WCAP	Chesapeake & Potomac Telephone Co	Washington, D. C.	640	469	500
WCAR	The Southern Radio Corp. of Texas	San Antonio, Tex.	833	360	100
WCAS	Dunwoody Industr. Inst.	Minneapolis, Minn.	1220	246	100
WCAT	S. Dak. State Sch. of Mines	Rapid City, S. Dak.	1250	240	50
WCAU	Durham & Co	Philadelphia, Pa.	1050	286	250
WCAV	J. C. Dice Electric Co	Little Rock, Ark.	833	360	10
WCAX	University of Vermont	Burlington, Vt.	833	360	50
WCAY	Kesselman O'Driscoll Music House	Milwaukee, Wis.	1150	261	250
WCAZ	Carthage College	Carthage, Ill.	1220	246	50
WCBA†	Chas. W. Heimbach	Allentown, Pa.	1070	280	5
WCBC	Univ. of Michigan	Ann Arbor, Mich.	1070	280	200

*This Company operates both stations
†Affiliated with station WSAN

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WCBD	Wilbur Glenn Voliva	Zion, Ill.	870	345	500
WCBN	Uhalt Radio Co.	New Orleans, La.	1140	263	5
WCK	Stix, Baer & Fuller Co.	St. Louis, Mo.	833	360	100
WCM	University of Texas	Austin, Tex.	833	360	500
WCX	Detroit Free Press	Detroit, Mich.	580	517	500
WDAE	Tampa Daily Times	Tampa, Fla.	833	360	250
WDAF	The Kansas City Star	Kansas City, Mo.	730	411	500
WDAG	J. L. Martin	Amarillo, Tex.	1140	263	100
WDAH	Trinity Methodist Church	El Paso, Tex.	1120	268	100
WDAK	Hartford Courant	Hartford, Conn.	1150	261	100
WDAO	Automotive Electric Co.	Dallas, Tex.	833	360	50
WDAP	Board of Trade	Chicago, Ill.	833	360	1000
WDAR	Lit Brothers	Philadelphia, Pa.	760	395	500
WDAS	Samuel A. Waite	Worcester, Mass.	833	360	10
WDAU	Slocum & Kilburn	New Bedford, Mass.	833	360	100
WDAY	Radio Equip. Corp.	Fargo, N. Dak.	1230	244	50
WDBC	Kirk, Johnson & Co., Inc.	Lancaster, Pa.	1160	259	50
WDM	Grace Church of the Covenant	Washington, D. C.	1280	234	50
WDZ	James L. Bush	Tuscola, Ill.	1080	278	10
WEAA	Frank D. Fallain & (Police Dept.)	Flint, Mich.	1070	280	10
WEAF	American Tel. & Tel. Co.	NewYork City, N.Y.	610	492	500
WEAH	Wichita Board of Trade	Wichita, Kans.	1070	280	100
WEAI	Cornell University	Ithaca, N. Y.	1050	286	500
WEAJ	Univ. of South Dakota	Vermillion, S. Dak.	1060	283	200
WEAM	Borough of No. Plainfield	N. Plainfield, N. J.	1190	252	100
WEAN	The Shepard Company	Providence, R. I.	1100	273	100
WEAO	Ohio State University	Columbus, Ohio	833	360	500
WEAP	Mobile Radio Co., Inc.	Mobile, Ala.	833	360	100
WEAR	Balto. American & News Pub. Co.	Baltimore, Md.	833	360	50
WEAS	The Hecht Co.	Washington, D. C.	833	360	100
WEAU	Davidson Bros. Co.	Sioux City, Iowa	833	360	100
WEAY	Iris Theater	Houston, Tex.	833	360	500
WEB	Benwood Co., Inc.	St. Louis, Mo.	1100	273	250
WEV	Hurlburt-Still Electrical Co.	Houston, Tex.	833	360	100
WEW	St. Louis University	St. Louis, Mo.	1150	261	100
WFAA	Dallas News & Dallas Journal	Dallas, Texas	630	476	500
WFAB	Carl F. Woese	Syracuse, N. Y.	1280	234	100
WFAF	H. C. Spratley Co.	Poughkeepsie, N. Y.	1100	273	20
WFAH	Electric Supply Co.	Port Arthur, Tex.	1270	236	50
WFAJ	Hi-Grade Wireless Instrument Co.	Asheville, N. C.	833	360	50
WFAM	Times Publishing Co.	St. Cloud, Minn.	833	360	20
WFAN	Hutchinson Elec. Serv. Co.	Hutchinson, Minn.	833	360	100
WFAQ	Missouri Wesleyan College	Cameron, Mo.	833	360	10
WFAT	The New Columbus College	Sioux Falls, S. D.	1160	258	50
WFAV	University of Nebraska	Lincoln, Nebr.	1090	275	500
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGAL	Lancaster Electric Supply & Construction Co.	Lancaster, Pa.	1210	248	50
WGAN	Cecil E. Lloyd	Pensacola, Fla.	833	360	50
WGAQ	Glenwood Radio Corp.	Shreveport, La.	833	360	100
WGAW	Ernest C. Albright	Altoona, Pa.	1150	261	100
WGAZ	South Bend Tribune	South Bend, Ind.	833	360	250
WGI	Am. Rad. & Research Corp.	Medford Hillside, Mass.	833	360	100
WGL	Thos. F. J. Howlett	Philadelphia, Pa.	833	360	250
WGR	Federal Tel. & Tel. Co.	Buffalo, N. Y.	940	319	750
WGV	Interstate Elec. Co.	New Orleans, La.	1240	242	100
WGY	General Electric Co.	Schenectady, N. Y.	790	380	1000
WHA	University of Wisconsin	Madison, Wis.	833	360	500
WHAA	State Univ. of Iowa	Iowa City, Iowa	620	484	500

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WHAB	The Clark W. Thompson Co.	Galveston, Tex.	833	360	200
WHAD	Marquette University	Milwaukee, Wis.	1070	280	100
WHAG	Univ. of Cincinnati	Cincinnati, Ohio	1350	222	200
WHAH	Hafer Supply Co.	Joplin, Mo.	1060	283	250
WHAK	Roberts Hardware Co.	Clarksburg, W. Va.	1260	238	15
WHAM	Univ. of Rochester	Rochester, N. Y.	1060	283	100
WHAP	Otto & Kuhns	Decatur, Ill.	833	360	50
WHAR	Paramount Radio&Elec.Co.	Atlantic City, N. J.	1300	231	10
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAV	Wilmington Elec. Spec. Co.	Wilmington, Del.	833	360	50
WHAZ	Rensselaer Polytechnic Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Automotive and Electrical School	Kansas City, Mo.	730	411	500
WHK	The Radiovox Co.	Cleveland, Ohio	1060	283	100
WHN	Loew's State Theatre Studio	NewYork City,N.Y.	833	360	100
WIAB	Joslyn Automobile Co.	Rockford, Ill.	1190	252	50
WIAC	Galveston Tribune	Galveston, Tex.	833	360	100
WIAD	Howard R. Miller	Philadelphia, Pa.	1180	254	100
WIAF	Gustav A. De Cortin	New Orleans, La.	1280	234	10
WIAI	The Heer Stores Co.	Springfield, Mo.	1190	252	20
WIAJ	Fox River Valley Radio Supply Co.	Neenah, Wis.	1340	224	20
WIAK	Journal-Stockman Co.	Omaha, Nebr.	1080	278	200
WIAO	School of Eng. of Milwaukee	Milwaukee, Wis.	833	360	100
WIAQ	Chronicle Pub. Co.	Marion, Ind.	1330	225	10
WIAR	Paducah Evening Sun	Paducah, Ky.	833	360	100
WIAS	Home Electric Co.	Burlington, Iowa	833	360	100
WIAU	Amer. Trust & Savings Bk.	Le Mars, Iowa	833	360	20
WIK	K. & L. Elec. Co.	McKeesport, Pa.	1280	234	100
WIL	Continental Elec. Sup. Co.	Washington, D. C.	833	360	5
WIP	Gimbel Brothers	Philadelphia, Pa.	590	508	500
WJAD	Frank P. Jackson	Waco, Tex.	833	360	150
WJAF	Muncie Press & Smith Elec. Co.	Muncie, Ind.	833	360	10
WJAG	The Norfolk Daily News	Norfolk, Nebr.	1060	283	250
WJAK	Clifford L. White	Greentown, Ind.	1180	254	30
WJAM	D. M. Perham	Cedar Rapids, Iowa	1120	268	20
WJAN	Peoria Star Co.	Peoria, Ill.	1070	280	100
WJAQ	Capper Publications	Topeka, Kans.	833	360	100
WJAR	The Outlet Co.	Providence, R. I.	833	360	500
WJAS	Pittsburgh Radio Sup. Hse.	Pittsburgh, Pa.	1200	250	500
WJAT	Kelley-Vawter Jewelry Co.	Marshall, Mo.	833	360	10
WJAX	Union Trust Co.	Cleveland, Ohio	770	390	500
WJAZ	Edgewater Beach Hotel	Chicago, Ill.	670	448	1000
WJD	Denison Univ.	Granville, Ohio	1310	229	10
WJH	Wm. P. Boyer Co.	Washington, D. C.	1100	273	100
WJX	DeForest Rad. Tel. & Tel. Co.	Jersey City, N. J.	833	360	500
WJY	Radio Corp. of America	New York, N. Y.	740	405	500
WJZ	Radio Corp. of America	New York, N. Y.	660	454	500
WKAA	H. F. Parr	Cedar Rapids, Iowa	1120	268	100
WKAD	Charles Looff	East Providence,R.I.	1250	240	10
WKAF	W. S. Radio Supply Co.	Wichita Falls, Texas	833	360	100
WKAN	United Battery Serv. Co.	Montgomery, Ala.	1330	225	20
WKAP	Dutee W. Flint	Cranston, R. I.	833	360	50
WKAQ	Radio Corp. of P. R.	San Juan,Porto Rico	833	360	500
WKAR	Mich. Agri. College	East Lansing, Mich.	1070	280	500
WKAV	The Laconia Radio Club	Laconia, N. H.	1180	254	50
WKAY	Brenau College	Gainesville, Ga.	1070	280	10
WKY	WKY Radio Shop	OklahomaCity,Okla.	833	360	150
WLAG	Cutting & Washington Radio Corp.	Minneapolis, Minn.	720	416	500

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WLAH	Samuel Woodworth	Syracuse, N. Y.	1280	234	100
WLAJ	Waco Electric Supply Co.	Waco, Texas	833	360	50
WLAK	Vermont Farm Mach. Co.	Bellows Falls, Vt.	833	360	500
WLAL	Naylor Elec. Co.	Tulsa, Okla	833	360	100
WLAP	W. V. Jordan	Louisville, Ky.	833	360	15
WLAQ	A. E. Schilling	Kalamazoo, Mich.	1060	283	10
WLAV	The Electric Shop, Inc.	Pensacola, Fla.	1180	254	15
WLAW	N. Y. Police Dept.	NewYork City, N.Y.	833	360	500
WLAX	Greencastle Community Broadcasting Station	Greencastle, Ind.	1300	231	10
WLB	Univ. of Minnesota	Minneapolis, Minn.	833	360	5
WLW	Crosley Manufacturing Co.	Cincinnati, Ohio	970	309	500
WMAB	Radio Supply Co.	OklahomaCity, Okla.	833	360	100
WMAC	Clive B. Meredith	Cazenovia, N. Y.	1150	261	200
WMAF	Round Hills Radio Corp.	S. Dartmouth, Mass.	833	360	500
WMAH	General Supply Co.	Lincoln, Nebr.	1180	254	100
WMAJ	Daily Drovers Telegram	Kansas City, Mo.	1090	275	250
WMAK	Norton Laboratories, Inc.	Lockport, N. Y.	833	360	500
WMAL	Trenton Hardware Co.	Trenton, N. J.	1170	256	50
WMAN	First Baptist Church	Columbus, Ohio	1050	286	10
WMAP	Utility Battery Service, Inc.	Easton, Pa.	1220	246	50
WMAQ	Chicago Daily News	Chicago, Ill.	670	448	500
WMAV	Alabama Polytechnic Inst.	Auburn, Ala.	1200	250	750
WMAW	Wahpeton Elec. Co.	Wahpeton, N. Dak.	1180	254	50
WMAY	Kingshighway Pres. Church	St. Louis, Mo.	1070	280	100
WMAZ	Mercer University	Macon, Ga.	1120	268	50
WMC	The Commercial Pub. Co.	Memphis, Tenn.	600	500	500
WMU	Doubleday-Hill Elec. Co.	Washington, D. C.	1150	261	100
WNAC	Shepard Stores	Boston, Mass.	1080	278	100
WNAD	Univ. of Oklahoma	Norman, Okla.	833	360	100
WNAL	R. J. Rockwell	Omaha, Nebr.	1130	265	20
WNAN	Syracuse Radio Tel. Co.	Syracuse, N. Y.	1050	286	200
WNAP	Wittenberg College	Springfield, Ohio	1300	231	100
WNAQ	Charleston Radio Elec. Co.	Charleston, S. C.	833	360	20
WNAR	C. C. Rhodes	Butler, Mo.	1300	231	20
WNAT	Lenning Bros. Co.	Philadelphia, Pa.	833	360	250
WNAV	Peoples Tel. & Tel. Co.	Knoxville, Tenn.	1270	236	500
WNAW	Peninsular Radio Club	Fort Monroe, Va.	833	360	10
WNAX	Dakota Radio App. Co.	Yankton, S. D.	1230	244	100
WNJ	Shotten Radio Mfg. Co.	Albany, N. Y.	833	360	25
WOAC	Pagan Organ Co.	Lima, Ohio	1130	265	150
WOAD	Friday Battery & Elec. Co.	Sigourney, Iowa	833	360	20
WOAE	Midland College	Fremont, Nebr.	833	360	20
WOAF	Tyler Commercial College	Tyler, Texas	833	360	20
WOAG	Apollo Theatre	Belvidere, Ill.	1100	273	100
WOAH	Palmetto Radio Shop	Charleston, S. C.	833	360	100
WOAI	Southern Equip. Co.	San Antonio, Texas.	780	384	500
WOAL	William E. Woods	Webster Groves, Mo.	1310	229	100
WOAN	James D. Vaughan	Lawrenceburg, Tenn.	833	360	200
WOAO	Lyradion Mfg. Co.	Mishawaka, Ind.	833	360	50
WOAP	Kalamazoo College	Kalamazoo, Mich.	1160	283	100
WOAR	Henry P. Lundskow	Kenosha, Wis.	1310	229	50
WOAT	Boyd M. Hamp	Wilmington, Del.	833	360	50
WOAV	Pennsylvania Nat. Guard	Erie, Pa.	1240	242	100
WOAW	Sovereign Camp, Woodmen of the World	Omaha, Nebr.	570	526	500
WOAX	Franklyn J. Wolff	Trenton, N. J.	1250	240	500
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa	620	484	500
WOI	Iowa State College	Ames Iowa	833	360	500
WOK	Pine Bluff Co.	Arkadelphia, Ark.	1130	265	250
WOO	John Wanamaker	Philadelphia, Pa.	590	508	500
WOQ	Western Radio Co.	Kansas City, Mo.	833	360	500
WOR	L. Bamberger & Co.	Newark, N. J.	740	405	500
WOS	Mo. State Marketing Bur.	Jefferson City, Mo.	680	441	500
WPAB	Pennsylvania State College	State College, Pa.	1060	283	500

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WPAC	Donaldson Radio Co.	Okmulgee, Okla.	833	360	200
WPAH	Wisconsin Dept. of Markets	Waupaca, Wis.	833	360	500
WPAJ	Doolittle Radio Corp.	New Haven, Conn.	1120	268	10
WPAK	Agri. College of N. Dakota	Fargo, N. Dakota	833	360	50
WPAL	Avery & Loeb Elec. Co.	Columbus, Ohio	1050	286	100
WPAM	Auerbach & Geuttel	Topeka, Kans.	833	360	100
WPAP	Theodore D. Phillips	Winchester, Ky.	833	360	35
WPAQ	General Sales & Eng. Co.	Frostburg, Md.	833	360	10
WPAT	Saint Patrick's Cathedral	El Paso, Texas	833	360	20
WPAU	Concordia College	Moorhead, Minn.	833	360	20
WPAZ	Dr. John R. Koch	Charleston, W. Va.	1100	273	10
WPG	Nushawg Poultry Farm	New Lebanon, Ohio	1280	234	50
WQAA	Horace A. Beale, Jr.	Parkesburg, Pa.	833	360	500
WQAC	Gish Radio Service	Amarillo, Tex.	1280	234	100
WQAE	Moore Radio News Station	Springfield, Vt.	1090	275	50
WQAF	Sandusky Register	Sandusky, Ohio	1250	240	5
WQAH	Brock-Anderson Elec. E. Co.	Lexington, Ky.	1180	254	10
WQAL	Coles County Tel. & Tel.	Mattoon, Ill.	1160	259	10
WQAM	Electrical Equip. Co.	Miami, Fla.	1060	283	100
WQAN	Scranton Times	Scranton, Pa.	1070	280	50
WQAO	Calvary Baptist Church	New York City, N.Y.	833	360	100
WQAQ	Abilene Daily Reporter (West Texas Radio Co.)	Abilene, Tex.	833	360	50
WQAS	Prince-Walter Co.	Lowell, Mass.	1130	265	100
WQAV	Huntington & Guerry, Inc.	Greenville, S. C.	1160	259	15
WQAW	Catholic Univ. of Amer.	Washington, D. C.	1270	236	5
WQAX	Radio Equip. Co.	Peoria, Ill.	833	360	100
WRAA	Rice Institute	Houston, Tex.	833	360	200
WRAD	Taylor Radio Shop	Marion, Kans.	1210	248	10
WRAF	Radio Club, Inc.	Laporte, Ind.	1340	224	20
WRAH	Stanley N. Read	Providence, R. I.	1300	231	15
WRAL	Northern States Power Co.	St. Croix Falls, Wis.	1210	248	10
WRAM	Lombard College	Galesburg, Ill.	1230	244	250
WRAN	Black Hawk Elec. Co.	Waterloo, Iowa	1270	236	10
WRAO	St. Louis Radio Service Co.	St. Louis, Mo.	833	360	20
WRAV	Antioch College	Yellow Springs, O.	1240	242	100
WRAW	Avenue Radio Shop	Reading, Pa.	1260	238	10
WRAX	Flexon's Garage	Gloucester City, N.J.	1120	268	100
WRAY	Radio Sales Corp.	Scranton, Pa.	1070	280	100
WRAZ	Radio Shop of Newark	Newark, N. J.	1290	232	50
WRC	Radio Corp. of America	Washington, D. C.	640	469	500
WRK	Doron Bros. Elec. Co.	Hamilton, Ohio	833	360	200
WRL	Union College	Schenectady, N. Y.	833	360	500
WRM	Univ. of Illinois	Urbana, Ill.	833	360	500
WRR	City of Dallas, Police and Fire Signal Dept.	Dallas, Texas	833	360	20
WRW	Tarrytown Radio Research	Tarrytown, N. Y.	1100	273	150
WSAB	Southeast Missouri State Teachers College	Cape Girardeau, Mo.	833	360	100
WSAC	Clemson Agri. College	Clemson College, S.C.	833	360	500
WSAD	J. A. Foster Co.	Providence, R. I.	1150	261	150
WSAG	L. V. Davis & G. Prestman, Sr.	St. Petersburg, Fla.	1230	244	10
WSAH	A. J. Leonard, Jr.	Chicago, Ill.	1210	248	500
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	970	309	500
WSAJ	Grove City College	Grove City, Pa.	833	360	250
WSAL	Franklin Elec. Co.	Brookville, Ind.	1220	246	50
WSAN†	Allentown Radio Club	Allentown, Pa.	1310	229	10
WSAP	Seventh Day Adventist Church	New York, N. Y.	1140	263	250
WSAR	Doughty & Welch Elec. Co.	Fall River, Mass.	1180	254	10
WSAT	Donohoo-Ware Hardware Co.	Plainview, Texas	1120	268	20
WSAW	John J. Long, Jr.	Canandaigua, N. Y.	1090	275	10

†Affiliated with station WCBA

Active Broadcasting Stations, February 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WSAX	Chicago Radio Lab	Chicago, Ill	1120	268	20
WSAY	Irving Austin, Rep. Port Chester Cham. of Com.	Port Chester, N. Y.	1290	232	100
WSAZ	Chase Electric Shop	Pomeroy, Ohio	1160	259	50
WSB	Atlanta Journal	Atlanta, Ga	700	428	500
WSL	J. & M. Electric Co	Utica, N. Y	1100	273	100
WSY	Alabama Power Co	Birmingham, Ala	833	360	500
WTAB	Fall River Daily Herald Co.	Fall River, Mass	1210	248	10
WTAC	Penn Traffic Co	Johnstown, Pa	833	360	50
WTAF	Louis J. Gallo	New Orleans, La	1120	268	10
WTAG	Kern Music Co	Providence, R. I.	1160	259	10
WTAH	Carmen Ferro	Belvidere, Ill	1270	236	10
WTAJ	The Radio Shop	Portland, Maine	1270	236	10
WTAL	Toledo Radio & Elec. Co.	Toledo, Ohio	1190	252	10
WTAM	The Willard Stor. Batt. Co.	Cleveland, Ohio	770	389	1000
WTAN	Orndorff Radio Shop	Mattoon, Ill	1250	240	100
WTAP	Cambridge Radio&Elec.Co.	Cambridge, Ill	1240	242	50
WTAQ	S. H. Van Gorden & Son	Osseo, Wis	1330	225	100
WTAR	Reliance Elec. Co	Norfolk, Va	1070	280	100
WTAS	Chas. E. Erbstein	Elgin, Ill	1050	286	500
WTAT	The Edison Elec. Illuminating Co. of Boston	Boston, Mass. (Portable)	1220	246	100
WTAU	Ruegy Battery & Elec. Co.	Tecumseh, Nebr	833	360	10
WTAW	Agri. & Mech. Col. of Tex.	College Station, Tex.	1070	280	50
WTAX	Williams Hardware Co	Streator, Ill	1300	231	50
WTAY	Oak Leaves Broadcasting Station(Pioneer Pub.Co.)	Oak Park, Ill	1330	283	500
WTAZ	Thomas J. McGuire	Lambertville, N. J.	1060	283	15
WTG	Kansas State Agri. College	Manhattan, Kans	833	360	500
WWAB	Hoenig, Swern & Co	Trenton, N. J	1330	225	10
WWAC	Sanger Brothers	Waco, Texas	833	360	50
WWAD	Wright & Wright, Inc	Philadelphia, Pa	833	360	500
WWAE	Alamo Dance Hall	Joliet, Ill	1320	227	500
WWAF	Galvin Radio Supply Co.	Camden, N. J	1270	236	100
WWAO	Michigan College of Mines	Houghton, Mich	1230	244	250
WWI	Ford Motor Co	Dearborn, Mich	1100	273	50
WWJ	Evening News Ass'n	Detroit, Mich	580	517	500
WWL	Loyola University	New Orleans, La	1120	268	100

CORRECTION

The latter part of the second paragraph on page 35 of the January issue of Radiofax should be corrected to read as follows:

"proximately. Suppose we use No. 20 D.S.C. wire. The table gives *27.66* turns of wire per inch. The length of the winding will then be 85/*27.66* x 2.54 = 7.*8* cms., approximately. The table shows the value of inductance to lie between 339 and 564 microhenries. Interpolating, the inductance of the coil is found to be *541* microhenries."

The corrections are in italics.

GEOGRAPHICAL LIST OF BROADCASTING STATIONS

February 15, 1924

(See Alphabetical List for details)

Location	Station
Alabama	
Auburn	WMAV
Birmingham	WSY
Mobile	WEAP
Montgomery	WKAN
Alaska	
Juneau	KFIU
Arizona	
Phoenix	KDYW
	KFAD
	KFCB
Tucson	KFDH
Arkansas	
Arkadelphia	WOK
Conway	KFKQ
Fayetteville	KFDV
	KFMQ
Little Rock	KFLQ
	KFMB
	WCAV
California	
Bakersfield	KDZB
Berkeley	KRE
Burlingame	KFNZ
El Monte	KUY
Fresno	KMJ
Hollywood	KFAR
Long Beach	KFMY
	KSS
Los Angeles	KDZF
	KFI
	KFSG
	KHJ
	KJS
	KNV
	KNX
	KUS
	KWH
Modesto	KXD
Oakland	KGO
	KLS
	KLX
	KZM
Paso Robles	KFNL
Richmond	KFCM
Sacramento	KFBK
San Diego	KDPT
	KDYM
	KFBC
San Francisco	KPO
	KUO
San Jose	KQW
San Luis Obispo	KFBE
Santa Ana	KFAW
Santa Barbara	KFHJ
Santa Rosa	KFNV
Stanford Univ.	KFGH
Stockton	KJQ
	KWG
Colorado	
Boulder	KFAJ
Colorado Sprgs.	KFFQ
	KFKZ
Denver	KDZQ
Denver	KFAF
	KFDL
	KFEL
	KFLE
	KLZ
Greeley	KFKA
Gunnison	KFHA
Trinidad	KFBS
Connecticut	
Hartford	WDAK
New Haven	WPAJ
Storrs	WABL
Delaware	
Wilmington	WHAV
	WOAT
District of Columbia	
Washington	WABE
	WCAP
	WDM
	WEAS
	WIL
	WJH
	WMU
	WQAW
	WRC
Florida	
Jacksonville	WABG
Miami	WQAM
Pensacola	WGAN
	WLAV
St. Petersburg	WSAG
Tampa	WDAE
W. Palm Beach	WBBJ
Georgia	
Atlanta	WBBF
	WSB
Gainesville	WKAY
Macon	WMAZ
Hawaii	
Honolulu	KDYX
	KGU
	KYQ
Lihue	KFHS
Idaho	
Boise	KFAU
	KFDD
	KFFB
Kellogg	KFEY
Moscow	KFAN
Illinois	
Belvidere	WOAG
	WTAH
Cambridge	WTAP
Carthage	WCAZ
Chicago	KYW
	WAAF
	~~WDAP~~
	WJAZ
	WMAQ
	~~WSAH~~
	~~WSAX~~
Decatur	WBAO
	WHAP
Elgin	WTAS
Galesburg	WRAM
Joliet	WWAE
Lake Forest	WABA
Lincoln	WBBM
Mattoon	WQAL
	WTAN
Monmouth	WBBU
Oak Park	WTAY
Rockford	KFLV
	WIAB
Peoria	WJAN
	WQAX
Streator	WTAX
Tuscola	WDZ
Urbana	WRM
Zion	WCBD
Indiana	
Brookville	WSAL
Greencastle	WLAX
Greentown	WJAK
Indianapolis	WBBI
Laporte	WRAF
Marion	WIAQ
Mishawaka	WOAO
Muncie	WJAF
South Bend	WGAZ
West Lafayette	WBAA
Iowa	
Ames	WOI
Atlantic	KFLZ
Boone	KFGQ
Burlington	WIAS
Cedar Falls	KFJX
Cedar Rapids	KFLP
	WJAM
	WKAA
Davenport	WOC
Dexter	KFJV
Fort Dodge	KFER
	KFJY
Iowa City	WHAA
Lamoni	KFFV
Le Mars	KFCY
	WIAU
Marshalltown	KFJB
Ottumwa	KFJL
Shenandoah	KFNF
Sigourney	WOAD
Sioux City	KFMR
	WEAU
Waterloo	WRAN
Kansas	
Anthony	WBL
Hutchinson	KFHX
Iola	KFID
Louisburg	KFIL
Manhattan	WTG
Marion	WRAD
Milford	KFKB
Peabody	KFNX
Topeka	WJAQ
	WPAM
Towanda	KFJW
Wichita	WEAH

Geographical List of Broadcasting Stations, February 15, 1924
(See Alphabetical List for details)

Kentucky
Lexington..... WQAH
Louisville...... WHAS
WLAP
Paducah...... WIAR
Winchester.... WPAP

Louisiana
Alexandria..... KFFY
Baton Rouge... KFGC
Franklinton.... KFLD
New Orleans... WAAB
WAAC
WABZ
WBBS
WCAG
WCBN
WGV
WIAF
WTAF
WWL
Shreveport..... KFDX
KFHF
WGAQ

Maine
Bangor........ WABI
Portland....... WTAJ

Maryland
Baltimore...... WCAO
WEAR
Frostburg...... WPAQ

Massachusetts
Boston........ WNAC
WTAT
Fall River..... WSAR
WTAB
Lowell........ WQAS
Mattapoisett... WBBG
Medford Hillside WGI
New Bedford... WDAU
S. Dartmouth.. WMAF
Springfield..... WBZ
Worcester..... WABK
WDAS

Michigan
Ann Arbor..... WCBC
Berrien Springs. KFGZ
Dearborn...... WWI
Detroit........ KOP
WCX
WWJ
East Lansing... WKAR
Flint.......... WEAA
Houghton..... KFMW
WWAO
Kalamazoo..... WLAQ
WOAP
Menominee.... KFLB
Mt. Clemens... WABX
Petoskey...... WBBP
Port Huron.... WBBH
Rodgers....... WBBO
Saginaw....... WABM

Minnesota
Duluth........ KFMS
Hutchinson.... WFAN
Minneapolis.... KFDZ
KFEX
KFMT
WBAD
WBAH
WCAS
WLAG
WLB
Moorhead..... WPAU
Northfield..... KFMX
WCAL
St. Cloud...... WFAM

Mississippi
Coldwater..... KFNG

Missouri
Butler......... WNAR
Cameron...... WFAQ
Cape Girardeau. WSAB
Columbia...... WAAN
Independence.. KFIX
Jefferson City.. WOS
Joplin......... WHAH
Kansas City... WDAF
WHB
WMAJ
WOQ
Marshall...... WJAT
St. Joseph..... KFHD
St. Louis...... KFEZ
KFGJ
KSD
WCK
WEB
WEW
WMAY
WRAO
Springfield..... KFNH
WIAI
Warrensburg .. KFNJ
Webster Groves WOAL

Montana
Billings........ KFCH
Bozeman...... KFDO
Butte......... KFKV
KFLA
Havre......... KFBB
Helena........ KFNY
Missoula...... KFLW
Stevensville.... KFJR

Nebraska
Fremont....... WOAE
Hastings....... KFKX
Lincoln........ WFAV
WMAH
Norfolk....... WJAG
Oak.......... KFEQ
Omaha........ KFCZ
KFFX
WAAW
WIAK
WNAL
WOAW
Tecumseh..... WTAU
Univ. Place.... WCAJ
Utica......... KFGV
York.......... KFDR

Nevada
Sparks........ KFFR

New Hampshire
Laconia........ WKAV

New Jersey
Atlantic City... WHAR
Camden....... WABU
WWAF
Gloucester City. WRAX
Jersey City.... WJX
Lambertville... WTAZ
Newark....... WAAM
WABS
WBS
WOR
WRAZ
No-th Plainfield WEAM
Paterson....... WBAN
Trenton....... WMAL
WOAX
WWAB

New Mexico
Alburquerque... KFLR
Roswell....... KFMZ
State College... KOB

New York
Albany........ WNJ
Buffalo........ WGR
Canandaigua... WSAW
Canton........ WCAD
Cazenovia..... WMAC
Ithaca........ WEAI
Lockport...... WMAK
New York City WBAY
WEAF
WHN
WJY
WLAW
WQAO
WSAP
Port Chester... WSAY
Poughkeepsie... WFAF
Rochester...... WABO
WHAM
Rossville...... WBBR
Schenectady... WGY
WRL
Syracuse....... WBBE
WFAB
WLAH
WNAN
Tarrytown..... WRW
Troy.......... WHAZ
Utica......... WSL

North Carolina
Asheville...... WFAJ
Charlotte...... WBT
Wilmington.... WBBN

North Dakota
Fargo......... KFLY
WDAY
WPAK
Grand Forks... KFJM
KFJQ
Wahpeton .... WMAW

Geographical List of Broadcasting Stations, February 15, 1924
(See Alphabetical List for details)

Ohio	
Cincinnati	WAAD
	WHAG
	WLW
	WSAI
Cleveland	KDPM
	WHK
	WJAX
	WTAM
Columbus	WBAV
	WCAH
	WEAO
	WMAN
	WPAL
Dayton	WABD
Dover	WABP
Granville	WJD
Hamilton	WRK
Lima	WOAC
Newark	WBBA
New Lebanon	WPG
Pomeroy	WSAZ
Sandusky	WABH
	WQAF
Springfield	WNAP
Toledo	WABR
	WTAL
Wooster	WABW
Yellow Springs	WRAV
Oklahoma	
Bristow	KFJK
Chickasha	KFGD
Norman	WNAD
Oklahoma City	KFJF
	WKY
	WMAB
Okmulgee	WPAC
Tulsa	WLAL
Oregon	
Arlington	KFGL
Astoria	KFJI
Baker	KFDA
Corvallis	KFDJ
Hillsboro	KFFO
Hood River	KFHB
	KQP
Medford	KFAY
Pendleton	KFFE
Portland	KDYQ
	KFEC
	KFIF
	KGG
	KGN
	KGW
Pennsylvania	
Allentown	WCBA
	WSAN
Altoona	WGAW
Butler	WBR
Easton	WMAP
East Pittsburgh	KDKA
Erie	WOAV
Grove City	WSAJ
Harrisburg	WABB
	WBAK
Haverford	WABQ
Johnstown	WBBV
	WTAC
Lancaster	WDBC
	WGAL
McKeesport	WIK
Parkesburg	WQAA
Philadelphia	WABY
	WBBT
	WCAU
	WDAR
	WFI
	WGL
	WIAD
	WIP
	WNAT
	WOO
	WWAD
Pittsburgh	KQV
	WBBK
	WCAE
	WJAS
Reading	WBBD
	WRAW
Scranton	WQAN
	WRAY
State College	WPAB
Villanova	WCAM
Washington	WABT
Wilkes-Barre	WBAX
Porto Rico	
San Juan	WKAQ
Rhode Island	
Cranston	WKAP
Pawtucket	WBBQ
Providence	WEAN
	WJAR
	WKAD
	WRAH
	WSAD
	WTAG
South Carolina	
Charleston	WNAQ
	WOAH
Clemson College	WSAC
Greenville	WQAV
South Dakota	
Brookings	KFDY
Rapid City	WCAT
Sioux Falls	WFAT
Vermillion	WEAJ
Yankton	WNAX
Tennessee	
Knoxville	WNAV
Lawrenceburg	WOAN
Memphis	WMC
Nashville	WABV
Texas	
Abilene	WQAQ
Amarillo	WDAG
	WQAC
Austin	WCM
College Station	WTAW
Corsicana	KFNC
Dallas	KFFZ
	WDAO
	WFAA
Dallas	WRR
El Paso	WDAH
	WPAT
Fort Worth	KFJZ
	WBAP
Galveston	KFLX
	WHAB
	WIAC
Houston	KFCV
	WCAK
	WEAY
	WEV
	WRAA
Orange	KFGX
Plainview	WSAT
Port Arthur	WFAH
San Antonio	WCAR
	WOAI
San Benito	KFLU
San Marcos	KFMU
Tyler	WOAF
Waco	WJAD
	WLAJ
	WWAC
Wichita Falls	WKAF
Utah	
Ogden	KFCP
Salt Lake City	KDYL
	KFLH
	KZN
Vermont	
Bellows Falls	WLAK
Burlington	WCAX
Springfield	WQAE
Virginia	
Fort Monroe	WNAW
Norfolk	WBBW
	WTAR
Richmond	WBBL
Washington	
Aberdeen	KNT
Bellingham	KDZR
Everett	KFBL
Lacey	KGY
Neah Bay	KFHH
Pullman	KFAE
Seattle	KDZE
	KFHR
	KFJC
	KFOA
	KHQ
	KJR
	KTW
Spokane	KFIO
Tacoma	KFBG
	KFEJ
	KGB
	KMO
Walla Walla	KFCF
Wenatchee	KDZI
	KZV
Yakima	KFIQ
West Virginia	
Charleston	WPAZ
Clarksburg	WHAK

Geographical List of Broadcasting Stations, February 15, 1924
(See Alphabetical List for details)

Wisconsin	Milwaukee......WCAY	St. Croix Falls..WRAL
Fond du Lac...KFIZ	WHAD	Waupaca.......WPAH
Kenosha.......WOAR	WIAO	**Wyoming**
La Crosse......WABN	Neenah.........WIAJ	Casper.........KFEV
Madison.......WHA	Osseo..........WTAQ	Douglas........KFEV
		Laramie........KFBU

CANADIAN BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	The Calgary Herald......	Calgary, Alberta...	697	430	1000
CFCA	Star Pub. & Print. Co.....	Toronto, Ontario...	750	400	1000
CFCF	Marconi Wireless Telegraph Co. of Canada.........	Montreal, Quebec...	681	440	1000
CFCH	Abitibi Power & Paper Co.	Iroquois Falls, Ont.	750	400	250
CFCJ	La Cie de L'Evenement ...	Quebec, Quebec....	731	410	5
CFCK	Radio Supply Co., Ltd.....	Edmonton, Alberta	731	410	125
CFCL	Centennial Me. Church...	Victoria, B. C......	750	400	250
CFCN	W. W. Grant Radio, Ltd	Calgary, Alberta...	681	440	500
CFCO	Semmelhaack-Dickson,Ltd.	Bellevue, Quebec...	666	450	10
CFCQ	Radio Specialties, Ltd.....	Vancouver, B. C...	666	450	5
CFCR	Laurentide Air Service, Ltd	Sudbury, Ont......	731	410	......
CFCW	The Radio Shop..........	London, Ont.......	714	420	10
CFDC	Sparks Company..........	Nanaimo, B. C.....	697	430	......
CFQC	The Electric Shop, Ltd....	Saskatoon, Sask....	750	400	100
CFRC	Queens University........	Kingston, Ont......	666	450	......
CFUC	Univ. of Montreal........	Montreal, Quebec...	750	400	1000
CFXC	Westminster Trust Co.....	New Westminster, B. C...........	681	440	......
CHAC	Radio Engineers..........	Halifax, N. S......	750	400	......
CHBC	The Albertan Pub. Co....	Calgary, Alberta...	731	410	250
CHCB	Marconi Wireless Telegraph Co. of Canada.........	Toronto, Ont......	681	440	......
CHCD	Canadian Wireless & Elec. Co....................	Quebec, Quebec....	731	410	5
CHCE	Western Can. Radio Supply	Victoria, B. C......	750	400	10
CHCL	The Vancouver Merchants Exchange, Ltd.........	Vancouver, B. C...	681	440	1000
CHCM	Riley & McCormack, Ltd..	Calgary, Alberta...	681	440	......
CHCS	The Hamilton Spectator...	Hamilton, Ont.....	731	410	......
CHYC	Northern Elec. Co., Ltd..	Montreal, Quebec..	880	341	1000
CJCA	The Edmonton Journal,Ltd	Edmonton, Alberta.	666	450	250
CJCD	T. Eaton Co., Ltd........	Toronto, Ontario...	731	410	50
CJCE	Sprott-Shaw Radio Co....	Vancouver, B. C...	714	420	125
CJCI	Maritime Radio Corp., Ltd.	St. John, N. B.....	750	400	100
CJCM	J. L. Phillipe Landry......	Monti Joli, Quebec.	750	400	......
CJCN	Simons, Agnew & Co......	Toronto, Ontario...	731	410	1000
CJCX	Percival Wesley Shackleton	Olds, Alberta......	750	400	100
CJGC	London Free Press Printing Co., Ltd..........	London, Ontario....	697	430	100
CJSC	The Evening Telegram....	Toronto, Ontario...	697	430	250
CKAC	La Presse Pub. Co., Ltd...	Montreal, Quebec...	692	425	1000
CKCD	Vancouver Daily Province.	Vancouver, B. C...	731	410	1000
CKCE	Canadian Independent Telephone Co,........	Toronto, Ontario...	666	450	1000
CKCH	Canadian National Railways................	Ottawa, Ont.......	690	435	......
CKCI	Le Soleil, Ltd...........	Quebec, Quebec....	731	410	......
CKCK	Leader Pub. Co., Ltd.....	Regina, Sask.......	714	420	1000
CKCO	Dr. G. M. Geldert (for Ottawa Radio Assn.)....	Ottawa, Ont.......	750	400	......
CKCX	P. Burns & Co., Ltd......	Calgary, Alberta...	681	440	......
CKOC	Wentworth Radio Supply..	Hamilton. Ontario..	731	410	10
CKY	Manitoba Tel. System....	Winnipeg, Manitoba	666	450	1000

HOW CALL LETTERS ARE ASSIGNED

The Service Regulations of the International Radiotelegraphic Conventions provide that the call letters of stations in the international system must each be formed of a group of three letters which shall be distinguishable from one another. The London International Radiotelegraphic Conference made a partial allotment of call letters, among nations which signed the convention, and the International Bureau at Berne, with the consent of such nations, has modified and added to this assignment of call letters

Call Letters of Nations

AAA to AMZ...............Germany
ANA to APZ............Dutch Indies
AQA to AWZ................Norway
AXA to AXZ..................Poland
AYA to AYZ..............Venezuela
AZA to AZZ.........................
B.......................Great Britain
CAA to CEZ...................Chile
CFA to CKZ....Great Britain protect.
CLA to CMZ...................Spain
CNA to CNZ................Morocco
COA to COZ............Great Britain
CPA to CPZ.................Bolivia
CQA to CQZ................Monaco
CRA to CRZ......Portugal (Colonies)
CSA to CUZ................Portugal
CVA to CVZ................Rumania
CWA to CWZ...............Uruguay
CXA to CXZ...................Spain
CYA to CZZ.................Mexico
DAA to DSZ...............Germany
DTA to DTZ......Danzig (Free State)
DUA to DZZ...............Germany
EAA to EHZ.........Spain (Colonies)
EIA to EZZ.............Great Britain
F...France (Colonies and protectorates)
G.......................Great Britain
HAA to HAZ..............Hungary
HBA to HBZ.............Switzerland
HCA to HCZ...............Ecuador
HDA to HEZ............Netherlands
HFA to HFZ....Kingdom of the Serbs, Croates, and Slovenes
HGA to HHZ.................Siam
HIA to HIZ......Dominican Republic
HJA to HKZ...............Colombia
HLA to HNU..................Spain
HNV to HNZ.......... New Hebrides
HOA to HZZ.....France (Colonies and protectorates)
I.....................Italy (Colonies)
J...............................Japan
KAA to KAY...............Germany
KAZ.............Danzig (Free State)
KBA to KBZ...............Germany
KCA to KCZ..................Latvia
KDA to KZZ...........United States
LAA to LHZ.... ....Norway
LIA to LRZ...............Argentina
LSA to LUZ............Great Britain
LVA to LVZ..............Guatemala
LWA to LWZ...............Norway
LXA to LZZ...............Bulgaria
M.......................Great Britain
N......................United States
OAA to OBZ..................Peru
OCA to OFZ............Great Britain
OGA to OIZ................Denmark
OJA to OJZ..................Finland
OKA to OKZ.........Czecho-Slovakia
OLA to OMZ.............Netherlands
ONA to OTZ.......Belgium (Colonies)
OUA to OZZ...............Denmark
PAA to PIZ..............Netherlands
PJA to PJM..................Curacao
PJN to PJZ............Dutch Guiana
PKA to PMZ...........Dutch Indies
PNA to PPZ....................Brazil
PQA to PSZ................Portugal
PTA to PVZ...................Brazil
PWA to PWZ...................Cuba
PXA to PZZ.............Netherlands
Q..........Reserved for abbreviations
RAA to RQZ...................Russia
RRA to RWZ........................
RXA to RXZ.................Panama
RYA to RYZ........Memel Territory
RZA to RZZ.........................
SAA to SMZ.................Sweden
SNA to STZ....................Brazil
SUA to SUZ...................Egypt
SVA to SZZ...................Greece
TAA to TEZ...................Turkey
TFA to TFZ..................Iceland
TGA to THZ.................Greece
TIA to TOZ.....................Spain
TPA to TUZ..................Norway
TVA to TZZ.............Netherlands
UAA to UMZ....France (Colonies and protectorates)
UNA to UNZ...Kingdom of the Serbs, Croates, and Slovenes
UOA to UOZ..................Austria
UPA to UZZ......................Italy
VAA to VGZ..................Canada
VHA to VKZ...............Australia
VLA to VMZ...........New Zealand
VNA to VNZ....Union of South Africa
VOA to VOZ...........Newfoundland
VPA to VSZ....Great Britain (Colonies and protectorates, autonomous)
VTA to VWZ........British India and Persian Gulf
VXA to VZZ...Great Britain (Colonies and protectorates)
W......................United States
XAA to XDZ..................Mexico
XEA to XMZ...........Great Britain
XNA to XSZ....................China
XTA to XZZ...........Great Britain
Y.......................Great Britain
Z.......................Great Britain

The call letters assigned to the United States are all three- and four-letter combinations beginning with the letter N and all beginning with the letter W, and all combinations from KDA to KZZ, inclusive. The international call letters assigned to the United States are reserved for Government stations and stations open to public and limited commercial service.

All combinations beginning with the letter N are reserved for Government stations, and, in addition, the combinations from WUA to WVZ and WXA to WZZ are reserved for stations of the United States Army.

During the war the combinations of three letters beginning with K, W, and N were exhausted, and it was necessary to assign combinations of four letters beginning with K, W, and N.

These assignments are as follows:

KDA-KZZ	Commercial	stations
NAA-NZZ	Navy	"
WAA-WTZ	Commercial	"
WUA-WVZ	Army	"
WWA-WWZ	Commercial	"
WXA-WZZ	Army	"

The combinations with three letters are used largely for ships and coast stations working with ships, although some broadcasting stations have been given three-letter calls where these are not required for ships or coast stations working with ships.

Broadcasting Stations come under the classification of Limited Commercial Stations, and are not permitted to accept or transmit public messages from other stations.

Broadcasting stations are divided into three classes, as follows:

Class A Stations—that is, stations equipped to use power not exceeding 500 watts. In this class the radio inspectors, in co-operation with the station owners, assign distinctive wave-lengths to each station so far as is possible in the area from 222 to 300 meters.

Class B Stations—that is, stations equipped to use from 500 to 1,000 watts. These stations are licensed on special wave-lengths from 300 to 345 and from 375 to 545 meters. There are forty distinct wave-lengths available in this range, and each is assigned to a certain locality, there being no duplications except for a few cases of use of the same wave by two localities, one on the Atlantic and the other on the Pacific Coast.

Class C Stations—comprising all stations already licensed for 360 meters. In this class no new licenses will be issued for stations on 360 meters. These stations are gradually being assigned a distinctive wave-length and are being placed in Class A. Stations which do not wish to move under the general plan may remain at 360 meters.

Wave-frequency allocations were given in the May Radiofax, and are included in Chap. 1 of 5th edition Handbook.

With few exceptions, call letters beginning with W are assigned to the broadcasting stations in the eastern half of the United States, and call letters beginning with K are assigned to stations in the western half.

Class B Stations are subject to the following requirements:

Modulation.—The system must be so arranged as to cause the generated radio-frequency current to vary accurately according to the sound impressed upon the microphone system.

Spare Parts.—Sufficient tubes and other material must be readily available to insure continuity and reliability of the announced schedule of service.

Antenna.—The antenna must be so constructed as to prevent swinging.

Signaling System.—Some dependable system must be provided for communication between the operating room and the studio.

Studio.—The radio equipment in the studio must be limited to that essential for use in the room. The room shall be so arranged as to avoid sound reverberation and to exclude external and unnecessary noises.

Programs.—The programs must be carefully supervised and maintained to insure satisfactory service to the public.

Music.—The use of mechanically-operated instruments is prohibited.

Broadcasting Development Class—To encourage scientific development of broadcasting and the apparatus used for this purpose, licenses of this class will be issued to owners of stations having transmitting and receiving equipment of their own design and manufacture. Such stations are to be used for the development and improvement of broadcasting and to have adequate laboratory and manufacturing facilities and personnel, with sufficient skill, training and experience to insure progress in development work and the best obtainable quality of broadcasting.

The Amateur Call letters begin with the numeral representing the district in which they are situated, followed by two or three letters. There are nine districts, the headquarters of the radio inspectors of the various districts being located at the addresses in the following list. The list also gives the territory included in each district:

1. Headquarters, Boston, Mass. (radio inspector, customhouse): Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
2. Headquarters, New York, N. Y. (radio inspector, customhouse): New York (County of New York, Staten Island, Long Island, and counties on the Hudson

River to and including Schenectady, Albany, and Rensselaer) and New Jersey (Counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson, and Ocean).

3. Headquarters, Baltimore, Md. (radio inspector, customhouse): New Jersey (all Counties not included in second district), Pennsylvania (Counties of Philadelphia, Delaware, all Counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, District of Columbia.

4. Headquarters, Savannah, Ga. (the work of this district is being performed by the radio inspector of the third district, customhouse, Baltimore, Md.): North Carolina, South Carolina, Georgia, Florida, Porto Rico.

5. Headquarters, New Orleans, La. (radio inspector, customhouse): Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, Oklahoma, New Mexico.

6. Headquarters, San Francisco, Calif. (radio inspector, customhouse): California, Hawaii, Nevada, Utah, Arizona.

7. Headquarters, Seattle, Wash. (radio inspector, 2301 L. C. Smith Building): Oregon, Washington, Alaska, Idaho, Montana, Wyoming.

8. Headquarters, Detroit, Mich. (radio inspector, Federal Building): New York (all Counties not included in second district), Pennsylvania (all Counties not included in third district), West Virginia, Ohio, Michigan (lower peninsula).

9. Headquarters, Chicago, Ill. (radio inspector, Federal Building): Indiana, Illinois, Wisconsin, Michigan (upper peninsula), Minnesota, Kentucky, Missouri, Kansas, Colorado, Iowa, Nebraska, South Dakota, North Dakota.

Canada follows the same system in assigning call letters to amateurs, which sometimes results in confusion.

The **Special Amateur** stations are assigned calls beginning with a numeral representing the district and having as the first letter of the combination "Z;" the **Experimental Stations** are assigned calls beginning with a figure representing the district, followed by the letter "X" and the **Training School** stations are assigned calls beginning with a figure representing the district, followed by the letter "T."

COMPLETE LIST OF EXPERIMENTAL RADIO STATIONS

(See Editorial comment, page 3)

DISTRICT 1

1XA	J. C. Ramsey, Andover, Mass.
1XAE	Westinghouse E. & M. Co., Springfield, Mass.
1XAF	Edison Elec. Illum. Co. of Boston, Boston, Mass.
1XAG	Edison Elec. Illum. Co. of Boston, Boston, Mass. (Portable).
1XAH	Univ. of Maine, Orono, Me.
1XAJ	Bu. of Fire Alarm & Police Tel., Waterbury, Conn.
1XAK	V. A. Hendrickson, Springvale, Conn.
1XAL	I. Vermilya, Mattapoisett, Mass.
1XAM	J. L. Reinartz, S. Manchester, Conn.
1XAN	Round Hills Radio Corp., South Dartmouth, Mass. (Portable).
1XAO	Radio Corp. of America, Belfast, Me.
1XAP	Radio Corp. of America, Belfast, Me.
1XAQ	S. Kruse & B. Phelps, Hartford, Conn.
1XAR	S. S. Heap, Atlantic, Mass.
1XB	M. Cronkhite, Greenwich, Conn.
1XD	Western Elec. Co., Green Harbor, Mass.
1XE	American R. & R. Corp., Medford Hillside, Mass.
1XH	Yale Univ., New Haven, Conn.
1XI	J. H. Hammond, Jr., Gloucester, Mass.
1XJ	Harvard Univ., Cambridge, Mass.
1XK	Boston College, Newton, Mass.
1XM	Mass. Inst. of Tech., Cambridge, Mass.
1XN	Wesleyan Univ., Middleton, Conn.
1XO	General Radio Co., Cambridge, Mass.
1XP	L. W. Bishop, Athol, Mass.
1XS	O. C. White, Worcester, Mass.
1XU	T.S.L. Kletoah, Stockbridge, Mass.
1XV	Round Hills Radio Corp., South Dartmouth, Mass.
1XW	F. H. Schnell, Hartford, Conn.
1XX	Brown Univ., Providence, R. I.
1XZ	Clark Univ., Worcester, Mass.

DISTRICT 2

2XA	E. M. Kinney, Schenectady, N. Y.
2XAB	C. N. Nobel, Schenectady, N. Y.
2XAC	J. B. Ferguson, Stapleton, N. Y.
2XAI	Westinghouse E. & M. Co., Newark, N. J.
2XAK	I. R. Nelson Co., Newark, N. J.
2XAL	International News Service, New York, N. Y.
2XAN	H. Alexander, Great Neck, N. Y.
2XAP	Rensselaer Poly. Inst., Troy, N. Y.
2XAQ	J. O. Smith, Valley Stream, N. Y.
2XAR	D. W. May, Inc., Newark, N. J.
2XAT	D. J. Pieri, New York, N.Y.
2XAU	Western Elec. Co., Eatontown, N. J.
2XAV	Western Elec. Co., New York, N. Y. (Portable).
2XAY	New York World, Metuchen, N. J.
2XAZ	General Elec. Co., Schenectady, N. Y.
2XB	Western Elec. Co., New York, N. Y.
2XBA	R. S. Ohl, New York, N. Y.
2XC	Ware Radio Co., New York, N. Y.
2XD	Radio Corp. of America, Tuckerton, N. J.
2XE	A. H. Grebe & Co., Richmond Hill, N. Y.
2XF	Western Elec. Co., Cliffwood, N. J.
2XG	DeForest Radio Tel. & Tel. Co., New York, N. Y.
2XH	Radio Corp. of America, Rye, N. Y.
2XI	General Elec. Co., Schenectady, N. Y.
2XJ	Western Elec. Co., Deal Beach, N. J.
2XK	Cockaday & Quinby, New York, N. Y.
2XL	Tarrytown Radio Research Lab., Tarrytown, N. Y.
2XM	Columbia Univ., New York, N. Y.
2XN	College of the City of New York, New York, N. Y.
2XNA	City College Radio Club, New York, N. Y.
2XNB	Townsend Harris Hall Radio Club, New York, N.Y.
2XO	W. G. Hudson, New York, N. Y.
2XP	L. G. Pacent, Winfield, N. Y.

River to and including Schenectady, Albany, and Rensselaer) and New Jersey (Counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson, and Ocean).

3. Headquarters, Baltimore, Md. (radio inspector, customhouse): New Jersey (all Counties not included in second district), Pennsylvania (Counties of Philadelphia, Delaware, all Counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, District of Columbia.

4. Headquarters, Savannah, Ga. (the work of this district is being performed by the radio inspector of the third district, customhouse, Baltimore, Md.): North Carolina, South Carolina, Georgia, Florida, Porto Rico.

5. Headquarters, New Orleans, La. (radio inspector, customhouse): Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, Oklahoma, New Mexico.

6. Headquarters, San Francisco, Calif. (radio inspector, customhouse): California, Hawaii, Nevada, Utah, Arizona.

7. Headquarters, Seattle, Wash. (radio inspector, 2301 L. C. Smith Building): Oregon, Washington, Alaska, Idaho, Montana, Wyoming.

8. Headquarters, Detroit, Mich. (radio inspector, Federal Building): New York (all Counties not included in second district), Pennsylvania (all Counties not included in third district), West Virginia, Ohio, Michigan (lower peninsula).

9. Headquarters, Chicago, Ill. (radio inspector, Federal Building): Indiana, Illinois, Wisconsin, Michigan (upper peninsula), Minnesota, Kentucky, Missouri, Kansas, Colorado, Iowa, Nebraska, South Dakota, North Dakota.

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2XNA	City College Radio Club, New York, N. Y.
2XNB	Townsend Harris Hall Radio Club, NewYork, N.Y.
2XO	W. G. Hudson, New York, N. Y.
2XP	L. G. Pacent, Winfield, N. Y.

2XQ	Union College, Schenectady, N. Y.
2XR	Radio Corp. of America, New York, N. Y.
2XS	Radio Corp. of America, Port Jefferson, N. Y.
2XT	Lowenstein Radio Co., Brooklyn, N. Y.
2XU	American Radio News Corp. New York, N. Y.
2XV	Radio Corp. of America, Cranford, N. J.
2XW	Radio Corp. of America, New York, N. Y.
2XX	Robt. F. Gowen, Ossining, N. Y.
2XY	American Tel. & Tel. Co., New York, N. Y.
2XZ	Fordham Univ., New York, N. Y.

DISTRICT 3

3XA	H. E. Miller, Philadelphia, Pa.
3XAB	Virginia Radio Co., Charlottesville, Va.
3XAH	D. B. Heilman, Reading, Pa.
3XAJ	Bliss Elec. School, Takoma Park, Md.
3XAM	Univ. of Virginia Radio Club, University, Va.
3XAN	F. J. Wolff, Trenton, N. J.
3XAO	H. F. Hastings, Washington, D. C.
3XAP	G. M. Phillips, Washington, D. C.
3XB	Phila. Elec. Co., Phila., Pa.
3XC	F. B. Chambers, Phila., Pa.
3XD	E. L. White, Cherrydale, Va.
3XG	Johns Hopkins Univ., Baltimore, Md.
3XI	Catholic Univ. of America, Washington, D. C.
3XJ	St. Joseph's College, Phila., Pa.
3XK	F. Strattner, Phila., Pa.
3XL	Washington Radio Labs., Washington, D. C.
3XM	Princeton Univ. Radio Club, Princeton, N. J.
3XN	Virginia Poly. Inst., Blacksburg, Va.
3XP	H. M. Neely, Delanco, N. J.
3XR	J. H. Rogers, Hyattsville, Md.
3XS	G. W. Carns, Phila., Pa.
3XV	T. Appleby, Phila., Pa.
3XW	H. A. Beale, Jr., Parkesburg, Pa.
3XX	R. S. Collmus & W. E. Lehr, Baltimore, Md.

DISTRICT 4

4XA	Emory Univ., Atlanta, Ga.
4XD	F. M. Laxton, Charlotte, N. C.
4XE	Wm. J. Lee & J. C. Cooper, Jr., Ortega, Fla.
4XK	C. J. Holdorf, Winter Park, Fla.
4XL	Mercer Univ., Macon, Ga.
4XP	Aeromarine Airways, Inc., Key West, Fla.
4XQ	E. Richard Hall, St. Petersburg, Fla.
4XR	J. E. Hodge, Savannah, Ga.

DISTRICT 5

5XA	Alabama Polytechnic Inst., Auburn, Ala.
5XAA	Hulburt-Still Elec. Co., Houston, Texas.
5XAB	Dr. L. M. Hunter, Little Rock, Ark.
5XAC	B. H. Woodruff, Conway, Ark.
5XAD	Gray & Gray, Orange, Tex.
5XAE	Mobile Radio Co., Mobile, Ala.
5XAF	Roswell B. Downing, Oklahoma, Okla.
5XAH	J. G. McInnish, Plainview, Tex.
5XAI	Arkansas Light & Power Co. Pine Bluff, Ark.
5XAJ	C. H. Baxter, Dublin, Tex.
5XAK	Jackson's Radio Engineering Lab., Waco, Texas.
5XAM	Harley L. Sherwood, Albuquerque, N. Mex.
5XAN	QRV Radio Co., Houston, Texas.
5XAO	L. J. N. duTreil, New Orleans, La.
5XAP	W. E. French, Fort Worth, Texas.
5XAQ	Edw. G. Conroy, San Antonio, Tex.
5XAR	G. L. Carrington, Little Rock, Ark.
5XAS	C. C. McNicol, El Paso, Tex.
5XAT	B. F. Painter, Chattanooga, Tenn.
5XAU	Agricultural & Mechanical College of Texas Radio Club, College Sta., Texas.
5XAV	Edgar A. Sahm, New Braunfels, Texas.
5XB	Agricultural & Mechanical College of Texas, College Station, Texas.
5XBA	P. B. Brooks, Montgomery, Ala.
5XBB	Southwest Gen. Elec. Co., Houston, Texas.
5XBC	J. O. Newbury, Dallas, Tex.
5XBD	Radio Phone Sales Co., Enid, Okla.
5XBE	Peoples Telep. & Teleg. Co., Knoxville, Tenn.
5XBF	H. H. Friend, Sand Springs, Okla.
5XBG	Baylor Univ., Waco, Texas.
5XD	New Mexico College Agri. & Mech. Arts, State College, N. M.
5XE	T. R. T. Co., Burrwood, La.
5XF	Howard Payne College, Brownwood, Texas.
5XG	Nat. Radio Mfg. Co., Oklahoma, Okla.

5XH Tropical Radio Teleg. Co., New Orleans, La.
5XJ G. W. Neel, Dublin, Texas.
5XK George P. Stout, Knoxville, Tenn.
5XL Thibodaux High School, Thibodaux, La.
5XM Electron Eng. Co., New Orleans, La.
5XN E. Hubner, Houston, Texas.
5XO George McDouglas, Houston Texas.
5XP E. M. Baker, San Antonio, Texas.
5XQ P. E. Lehde, New Orleans, La.
5XT E. C. Hull & H. S. Richards, Oklahoma City, Okla.
5XU Univ. of Texas, Austin, Tex.
5XV L. W. Hatry, Port Arthur, Texas.
5XW Univ. of Oklahoma, Norman, Okla.
5XX Tom L. Gray, Austin, Tex.
5XY Southern Radio Corp. of Texas, San Antonio, Tex.
5XZ St. Charles College, Grand Coteau, La.

DISTRICT 6

6XA Radio Specialty Shop, Oakland, Calif.
6XAD L. Mott, Avalon, Calif.
6XAE C. E. Thompson, San Francisco, Calif.
6XAH A. Wade, Jr., Los Angeles, Calif.
6XAI W. K. Asbill, San Diego, Calif.
6XAJ P. D. Allen, Oakland, Calif.
6XAK L. J. Meyberg Co., Los Angeles, Calif.
6XAL P. Oard, Stockton, Calif.
6XAM Warner Bros., Oakland, Calif.
6XAN Bryan H. Dennis, Fullerton, Calif.
6XAO G.M. Best, Piedmont, Calif.
6XAQ L. B. Benjamin, Los Angeles, Calif.
6XAR Great Western Radio Corp., Oakland, Calif.
6XAS B. E. Sawyer, Redlands, Calif.
6XAT Oliver S. Garretson, Eagle Rock, Calif.
6XAV W. W. Lindsay, Jr., Hollywood, Calif.
6XAX G. S. Corpe, El Monte, Cal.
6XAY C. R. Tinsley, Berkeley, Calif.
6XAZ L. R. Wilson, Tucson, Ariz.
6XB Mercantile Trust Co., San Francisco, Calif.
6XBA H. A. Duvall, Los Angeles, Calif.
6XBB R. M. Neits, San Francisco, Calif.
6XBC T. E. Nikirk, Los Angeles. Calif.
6XBD Los Angeles County Forestry Dept., Los Angeles, Calif. (Portable).
6XBE A. Johnson, Salt Lake City, Utah (Airplanes).
6XBG H. C. Wilson, Deseret News, Salt Lake City, Utah.
6XBH R. M. Potter, Clifton, Ariz.
6XBI W.W. Burnett, San Diego, Calif.
6XBJ D. B. McGown, San Francisco, Calif.
6XBK Federal Teleg. Co., San Francisco, Calif. (Port'ble)
6XBL B. H. Linden, Oakland, Calif.
6XBM Leland Stanford, Jr. Univ., Stanford Univ., Calif.
6XBN G. B. Ashe, Venice, Calif.
6XBO Los Angeles Co. Forestry Dept., Los Angeles, Calif.
6XBP N. E. Brown, Los Angeles, Calif.
6XC Atlantic-Pacific Radio Sup. Co., San Francisco, Calif.
6XD Western Radio Elec. Co., Los Angeles, Calif.
6XE C. D. Herrold, San Jose, Calif.
6XG Gen. Elec. Co., Oakland, Calif.
6XH H. Hoover, Jr., Stanford Univ., Calif.
6XI S. G. McMeen, Pasadena, Calif.
6XK R. P. MacKenzie, Los Angeles, Calif.
6XL General Petroleum Corp., Los Angeles. Calif.
6XM Univ. of Calif., Berkeley, Calif.
6XN Dr. A. E. Banks, San Diego, Calif.
6XO Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
6XQ Southern Calif. Edison Co., Los Angeles, Calif.
6XS R. B. Ashbrook, San Gabriel, Calif.
6XT Bible Inst. of Los Angeles, Los Angeles, Calif.
6XU San Joaquin L. & P. Corp., Fresno, Calif.
6XV Federal Teleg. Co., Palo Alto, Calif.
6XW R. C. Tavers & H. D. de la Montanya, Oakland, Cal.
6XX R. C. A., San Francisco, Calif.
6XY Earle C. Anthony, Inc., Los Angeles, Calif.
6XZ R. O. Shelton, M. D., Los Angeles, Calif.

DISTRICT 7

7XAA Amateur Radio Club of Seattle, Seattle, Wash.
7XAB F. A. Moore, Walla Walla, Wash.
7XAC W. J. Virgin, Medford, Ore.

7XAD	Benson Tech. School Student Body, Portland, Ore.
7XAE	Walter Henrich, Aberdeen, Wash.
7XAF	A. C. Dixon & Son, Stevensville, Mont. (near)
7XB	Montana State College, Bozeman, Mont.
7XBA	A. R. Wilson, Butte, Mont.
7XBB	F. F. Gray, Butte, Mont.
7XBC	H. E. Cutting, Bozeman, Mont.
7XBD	Radio Service Co., Portland, Ore.
7XC	V. I. Kraft, Seattle, Wash.
7XE	R. C. A., Seattle, Wash.
7XF	Northwestern Radio Mfg. Co., Portland, Ore.
7XH	Oregon Agri. College, Corvallis, Ore.
7XI	Hallock & Watson Radio Service, Portland, Ore.
7XJ	C. W. Peterson, Seattle, Wash.
7XK	Kilbourne & Clark Mfg. Co., Seattle, Wash.
7XL	Northwestern Electric Co., Portland, Ore.
7XM	Montana Power Co., Butte, Mont.
7XN	Montana Power Company, Thompson Falls, Mont.
7XO	Montana Power Co., Rainbow, Mont.
7XQ	Northwestern Electric Co., Underwood, Wash.
7XR	L. Wasmer, Seattle, Wash.
7XT	Boise High School, Boise, Idaho.
7XU	Rhodes Co., Seattle, Wash.
7XV	Kilbourne & Clark Mfg. Co., Tacoma, Wash.
7XW	State College of Washington, Pullman, Wash.
7XX	W. R. Rathbun, Anchorage, Alaska.
7XY	W. R. Rathbun, Anchorage, Alaska.
7XZ	University of Washington, Seattle, Wash.

DISTRICT 8

8XA	Univ. of Michigan, Ann Arbor, Mich.
8XAD	Federal Tel. & Tel. Co., Buffalo, N. Y.
8XAE	H. B. Joy, Mount Clemens, Mich.
8XAF	H. P. Hardesty, Highland Park, Mich.
8XAG	Doron Bros. Electric Co., Hamilton, Ohio.
8XAH	Ohio Mech. Inst., Cincinnati, Ohio.
8XAJ	Union Gas & Elec. Co., Cincinnati, Ohio.
8XAK	Wittenberg College, Springfield, Ohio.
8XAM	A. L. Kent, Binghamton, N. Y.
8XAN	C. F. Nichols, Webster, N.Y.
8XAO	V. G. Martin, Rochester, N. Y.
8XAP	West Penn Power Co., Connellsville, Pa.
8XAR	Tecla Co., Detroit, Mich.
8XAT	Superior Radio & Tel. Eq. Co., Columbus, Ohio.
8XAV	J. E. Page, Baldwinsville, N. Y.
8XAX	Radio Sales Corp., Scranton, Pa.
8XAY	Crosley Radio Corp., Cincinnati, Ohio.
8XAZ	K. E. Davis, Potsdam, N. Y.
8XBA	Penn. Power & Light Co., Frackville, Pa.
8XBB	Penn. Power & Light Co., Hauto, Pa.
8XBC	Penn. Power & Light Co., Hazleton, Pa.
8XBD	Radiovox Co., Cleveland, Ohio.
8XBE	A. R. Marcy, Syracuse, New York.
8XBF	H. J. Partridge, Dover, Ohio.
8XBH	Clarkson College of Tech., Potsdam, N. Y.
8XBI	Thomas W. Scott, Connellsville, Pa.
8XBJ	Michigan Limestone and Chemical Co., Rogers City, Mich.
8XBK	Wyandotte Transportation Co., Wyandotte, Mich.
8XBL	D. R. Inglis, Ann Arbor, Mich.
8XBM	R. C. Hiteshue, Parnassus, Pa.
8XBN	George P. Markoff, Cleveland, Ohio.
8XBO	J. W. Kidd, Niles, Ohio.
8XBP	A. B. Allen, Detroit, Mich.
8XBQ	C. E. Darr, Highland Park, Mich.
8XBR	Union Trust Co., Cleveland, Ohio.
8XBS	Univ. of City of Toledo, Toledo, Ohio.
8XBT	College of City of Detroit, Detroit, Mich.
8XBU	Michigan Agri. College, East Lansing, Mich.
8XD	Ford Motor Co., Dearborn, Mich.
8XE	Penna. State College, State College, Pa.
8XF	Kalamazoo College, Kalamazoo, Mich.
8XG	Willard Storage Battery Co., Cleveland, Ohio.
8XGB	Doubleday-Hill Electric Co., Pittsburgh, Pa.
8XH	C. B. Meredith, Cazenovia, N. Y.
8XK	F. Conrad, Pittsburgh, Pa.
8XL	Ford Motor Co., Northville, Mich.
8XN	Federal Tel. & Tel. Co. Buffalo, N. Y.
8XO	Westinghouse Elec. & Mfg. Co., Cleveland, Ohio.

8XP	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
8XQ	Rochester Gas & Elec. Co., Rochester, N. Y.
8XR	Entreken Elec. Co., Columbus, Ohio.
8XS	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
8XU	Cornell Univ., Ithaca, N.Y.
8XV	F. S. McCullough, Wilkinsburg, Pa.
8XY	West Penn. Power Co., Pittsburgh, Pa.
8XZ	Supervisor of Radio, 8th Dist., Detroit, Mich.

DISTRICT 9

9XAC	Karlowa Radio Corp., Davvenport, Iowa.
9XAR	Central High School, Omaha, Nebr.
9XAS	M. G. Sateren, Mayville, N. Dak.
9XAT	Cutting&Washington Radio Corp., Minneapolis, Minn.
9XAW	Michigan College of Mines, Houghton, Mich.
9XAX	D. C. Wallace, Minneapolis, Minn.
9XAY	M. G. Sateren, Houghton, Mich.
9XAZ	Univ. of Iowa, Iowa City, Iowa.
9XBA	F. J. Marco, Chicago, Ill.
9XBB	Iowa State College, Ames, Iowa.
9XBC	G. C. Shalkhauser & Bradley Polytechnic Inst., Peoria, Ill.
9XBD	W. E. Schweitzer, Chicago, Ill.
9XBE	Ott Radio, Inc., La Crosse, Wis.
9XBG	E. T. Flewelling, Highland Park, Ill.
9XD	Dodge's Tel. & Radio Inst., Valparaiso, Ind.
9XG	A. A. Howard, Chicago, Ill.
9XH	City of Fort Wayne, Fort Wayne, Indiana.
9XI	Univ. of Minnesota, Minneapolis, Minn.
9XJ	Univ. of Illinois, Urbana, Ill.
9XM	Univ. of Wisconsin, Madison, Wis.
9XN	Chicago Radio Lab., Chicago, Ill.
9XO	Morkrum Co., Chicago, Ill.
9XS	Lombard College, Galesburg, Ill.
9XW	Westinghouse Elec. & Mfg. Co., Hastings, Nebr.
9XY	Westinghouse Elec. & Mfg. Co., Chicago, Ill.
9XZ	P. G. Busey, Urbana, Ill.

RADIO IN AUSTRALIA

We are in receipt of the following conspectus concerning radio in Australia.

Any person being a natural-born British subject is granted a broadcasting license by producing the specified evidence, to the satisfaction of the officials, of financial and technical capability to provide and maintain a reliable service for a period of five years.

After the license has been issued, the owner must sign a contract supported by a financial guarantee of £1000 guaranteeing a satisfactory service for the five-year period.

The owner may apply for the use of any power between 500 and 5000 watts, which will be fixed by the officials.

All material broadcast is subject to censorship as the officials determine. No work or part of work in which a copyright subsists may be broadcast except with the consent of the owner of the copyright. Any news or information of any kind is not permitted to be broadcast which is published in any newspaper or obtained, collected, collated or co-ordinated by any newspaper or association, etc., except with the full consent in writing first having been obtained and upon such payment and conditions as are mutually agreed upon by the owner and the station.

The officials also reserve the right to curtail the hours of broadcasting at any time, if found to be advisable.

A receiving license is issued to any person on payment of the annual license fee of 10s. together with the annual subscription payable to the broadcasting station. A holder of a receiving license is not permitted to transfer or dispose of the licensed installation to any person not holding a receiving license.

The receiving apparatus may be purchased or hired by a person holding a receiving license and shall be approved by an authorized officer and marked accordingly. The receiver is constructed so as to respond only to the wave-length indicated or any wave-length not differing more than 10 per centum as specified. The receivers do not respond to any wave-lengths outside of the specified limits.

Any holder of a receiving license who desires to receive at the same address from more than one broadcasting station is permitted to have separate receivers, or have his altered so as to respond to the wave-length of the other stations he desires to hear.

No receivers are permitted that contain a tube or tubes so connected as to cause regeneration.

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
2BS	Broadcasters Sydney, Ltd.	Sydney, New South Wales...........	857	350	500
2FC	Farmers & Co............	Sydney, New South Wales...........	273	1100	5000
2FL	Farmers & Co............	Sydney, New South Wales...........	389	770	500
3AR	Associated Radio Co. of Australia..............	Melbourne, Victoria.	625	480	1600
3JO	Broadcasting Co. of Australia.................	Melbourne, Victoria.	750	400	500
3LO	Broadcasting Co. of Australia.................	Melbourne, Victoria.	174	1720	5000
5MA	Millswood Auto & Radio Co..................	Adelaide, S. Australia	353	480	3000
6AR	Associated Radio Co......	Perth, S. Australia..	833	360	1600
6WF	Westralian Farmers, Ltd..	Perth, W. Australia.	240	1250	5000

ONE OF MANY

Gentlemen:

I received my first assignment of Radiofax yesterday, and must say that I did not expect anything like it when I bought the Lefax. It is worth its weight in gold, and I have my doubts that the radio text books that are advertised for a very handsome price in all the magazines can come anywhere near to it.

Lefax is always new, never gets old or tiresome reading, and all I can say for it is a good word and I never made a better investment.

Am enclosing my renewal although I have another year to go, but it has proven its worth, so I am not going to delay.

LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Corrected to June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse E. & M. Co.	East Pittsburgh, Pa.	920	326	1000
KDPM	Westinghouse E. & M. Co.	Cleveland, Ohio....	1110	270	500
KDPT	Southern Electrical Co.....	San Diego, Calif....	1230	244	100
KDYL	Newhouse Hotel..........	Salt Lake City,Utah	833	360	100
KDYM	Savoy Theatre...........	San Diego, Calif....	1070	280	50
KDYQ	Oregon Inst. of Technology	Portland, Ore.......	833	360	50
KDZB	Frank E. Siefert..........	Bakersfield, Calif...	1250	240	100
KDZE*	The Rhodes Co..........	Seattle, Wash.......	1110	270	100
KDZI	Electric Supply Co.......	Wenatchee, Wash..	833	360	50
KDZQ	Nichols Academy of Danc'g	Denver, Colo........	833	360	10
KDZR	Bellingham Publishing Co.	Bellingham, Wash..	1150	261	50
KFAD	McArthur Bros. Co.......	Phoenix, Ariz.......	833	360	100
KFAE	State College of Wash.....	Pullman, Wash......	910	330	500
KFAF	Western Radio Corp......	Denver, Colo........	1080	278	500
KFAJ	University of Colorado....	Boulder, Colo......	833	360	100
KFAN	The Electric Shop........	Moscow, Idaho.....	833	360	50
KFAR	Studio Lighting Service Co.	Hollywood, Calif....	1070	280	150
KFAU	Boise High School........	Boise, Idaho........	1110	270	150
KFAW	The Radio Den..........	Santa Ana, Calif....	1070	280	10
KFAY	W. J. Virgin.............	Medford, Ore.......	1060	283	50
KFBB	F. A. Buttrey & Co.......	Havre, Mont........	833	360	100
KFBC	W. K. Azbill.............	San Diego, Calif....	1080	278	15
KFBE	Reuben H. Horn.........	San Luis Obispo,Cal.	1240	242	50
KFBG	First Presbyterian Church.	Tacoma, Wash......	833	360	50
KFBK	Kimball-Upson Co........	Sacramento, Calif...	1060	283	100
KFBL	Leese Bros..............	Everett, Wash......	1340	224	10
KFBS	Trinidad Gas & Electric Supply Co. & Chronicle News Publishing Co.....	Trinidad, Colo......	833	360	15
KFBU	Bishop N. S. Thomas.....	Laramie, Wyo......	1060	283	50
KFCB	Nielson Radio Supply Co..	Phoenix, Ariz.......	1260	238	10
KFCF	Frank A. Moore..........	Walla Walla, Wash.	833	360	100
KFCH	Elec. Service Station, Inc..	Billings, Mont......	833	360	10
KFCP	Ralph W. Flygare........	Ogden, Utah........	833	360	25
KFCV	Fred Mahaffey, Jr........	Houston, Tex.......	833	360	10
KFCY	Western Union College....	Le Mars, Iowa.....	1190	252	50
KFCZ	Omaha Central H. S......	Omaha, Nebr.......	1160	259	50
KFDA	Adler's Music Store.......	Baker, Ore..........	833	360	5
KFDD	St. Michael Cathedral.....	Boise, Idaho.......	1190	252	10
KFDH	University of Arizona.....	Tucson, Ariz........	1120	268	50
KFDJ	Oregon Agri. College......	Corvallis, Ore......	833	360	50
KFDO	H. E. Cutting............	Bozeman, Mont....	1210	248	50
KFDR	Bullock's Hardware Co....	York, Nebr........	833	360	10
KFDV	Gilbrech & Stinson.......	Fayetteville, Ark...	833	360	10
KFDX	First Baptist Church......	Shreveport, La.....	833	360	100
KFDY	S. Dak. State College.....	Brookings, S. Dak..	833	360	150
KFDZ	Harry O. Iverson.........	Minneapolis, Minn..	1300	231	5
KFEC	Meier & Frank Co........	Portland, Ore.......	1210	248	50
KFEL	Winner Radio Corp.......	Denver, Colo.......	1180	254	150
KFEQ	J. L. Scroggin...........	Oak, Nebr.........	1120	268	100
KFER	Auto. Elec. Service Co....	Fort Dodge, Iowa..	1300	231	10
KFEV	Felix-Thompson Radio Shop	Casper, Wyo.......	1140	263	250
KFEX	Augsburg Seminary.......	Minneapolis, Minn..	1150	261	100
KFEY	Bunker Hill & Sullivan Mining & Concentr. Co..	Kellogg, Idaho......	833	360	10
KFEZ	Assoc. Eng. Soc. of St. Louis	St. Louis, Mo......	1210	248	250
KFFB	Jenkins Furniture Co......	Boise, Idaho.......	1250	240	10
KFFE	Eastern Oregon Radio Co..	Pendleton, Ore.....	833	360	10
KFFO	Dr. E. H. Smith..........	Hillsboro, Ore......	1310	229	5
KFFP	First Baptist Church......	Moberly, Mo......	1130	266	50

*This Company also operates station KFOA

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFFQ	Marksheffel Motor Co.....	Colo. Springs, Colo..	1050	286	100
KFFR	Nevada State Journal.....	Sparks, Nev.........	1330	225	10
KFFV	Graceland College.........	Lamoni, Iowa.......	1070	280	100
KFFX	The McGraw Co...........	Omaha, Nebr.......	1080	278	100
KFFY	Pincus & Murphey, Inc....	Alexandria, La......	1090	275	50
KFFZ	A. G. Barnes Amus. Co....	Dallas,Tex.,Portable	1330	225	20
KFGC	Louisiana State Univ......	Baton Rouge, La...	1180	254	100
KFGD	Chickasha Rad. & Elec. Co.	Chickasha, Okla....	1210	248	200
KFGH	Leland Stanford University	Stanford Univ.,Calif	1100	273	500
KFGL	Arlington Garage..........	Arlington, Ore......	1280	234	5
KFGQ	Crary Hardware Co.......	Boone, Iowa........	1330	225	10
KFGV	Heidbreder Radio Sup. Co.	Utica, Nebr........	1340	224	10
KFGX	First Presbyterian Church.	Orange, Tex........	1200	250	500
KFGZ	Emmanuel Missionary Col.	Berrien Sprgs,Mich.	1050	286	500
KFHA	Western State Col. of Colo.	Gunnison, Colo.....	1190	252	50
KFHB	P. L. Boardwell..........	Hood River, Ore....	1070	280	5
KFHD	Uts Electric Co...........	St. Joseph, Mo.....	1330	225	100
KFHF	Central Christian Church..	Shreveport, La.....	1130	265	150
KFHH	A. A. McCue.............	Neah Bay, Wash...	1150	261	50
KFHJ	Fallon & Company........	Santa Barbara, Calif.	833	360	100
KFHR	Star Elec. & Radio Co.....	Seattle, Wash......	1060	283	50
KFHX	Robert W. Nelson.........	Hutchinson, Kans...	1310	229	150
KFI	Earle C. Anthony (Inc.)...	Los Angeles, Calif...	640	469	500
KFID	Ross Arbuckle............	Iola, Kans..........	1220	246	20
KFIF	Benson Polytechnic School	Portland, Ore.......	833	360	100
KFIL	Windisch El. Farm Eq. Co.	Louisburg, Kans....	1280	234	30
KFIO	North Central H. S........	Spokane, Wash.....	1190	252	50
KFIQ	Yakima Valley Radio Broadcasting Assn.......	Yakima, Wash.....	1240	242	50
KFIU	Alaska Elec. Light & Power Co..................	Juneau, Alaska.....	1330	225	10
KFIX	Reorganized Church of Jesus Christ of Latter Day Saints.................	Independence, Mo..	1250	240	250
KFIZ	Daily Commonwealth—O. A. Huelsman...........	Fond du Lac, Wis..	1100	273	100
KFJB	Marshall Elec. Co.........	Marshalltown, Iowa	1210	248	10
KFJC	Seattle Post-Intelligencer..	Seattle, Wash......	1110	270	100
KFJF	Nation Radio Mfg. Co.....	OklahomaCity,Okla.	1190	252	20
KFJI	Liberty Theatre—E. E. Marsh................	Astoria, Ore........	1190	252	10
KFJK	Delano Radio & Elec. Co..	Bristow, Okla......	1280	234	100
KFJL	Hardsace Mfg. Co.........	Ottumwa, Iowa.....	1240	242	10
KFJM	Univ. of North Dakota....	Grand Forks, N. D..	1070	280	100
KFJQ	Valley Radio Div. of Elec. Constr. Co............	Grand Forks, N. D.. (Portable).......	1070	280	5
KFJR	Ashley C. Dixon & Son....	Stevensville, Mont..	1160	259	50
KFJV	Thomas H. Warren........	Dexter, Iowa.......	1340	224	10
KFJX	Iowa State Teachers Col...	Cedar Falls, Iowa..	1070	280	50
KFJY	Tunwall Radio Co.........	Ft. Dodge, Iowa ...	1220	246	50
KFJZ	Texas National Guard 112th Cavalry..........	Ft. Worth, Texas...	1180	254	20
KFKA	Colo. State Teachers Col..	Greeley, Colo.......	1100	273	50
KFKB	Brinkley-Jones Hospital Assn.................	Milford. Kansas....	1050	286	500
KFKQ	Conway Radio Labs.......	Conway, Ark.......	1200	250	100
KFKV	F. F. Gray...............	Butte, Mont........	1060	283	50
KFKX	Westinghouse E. & M. Co.	Hastings, Nebr.....	880	341	1000
KFKZ	Nassour Bros. Radio Co...	ColoradoSprgs,Colo.	1280	234	10
KFLA	Abner R. Willson.........	Butte, Mont........	1060	283	5
KFLB	Signal Electric Mfg. Co....	Menominee, Mich..	1210	248	50
KFLD	Paul E. Greenlaw.........	Franklinton, La.....	1280	234	20
KFLE	National Educ. Service....	Denver, Colo.......	1120	268	25
KFLH	Erickson Radio Co., Inc...	Salt Lake City, Utah	1150	261	50

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFLP	Everetts M. Foster	Cedar Rapids, Iowa	1250	240	20
KFLQ	Bissell Radio Shop	Little Rock, Ark.	1150	261	20
KFLR	Univ. of New Mexico	Albuquerque, N. Mex	1180	254	100
KFLU	Rio Grande Radio Supply House	San Benito, Texas	1270	236	20
KFLV	Rev. A. T. Frykman	Rockford, Ill	1310	229	100
KFLW	Missoula Elec. Supply Co.	Missoula, Mont.	1280	234	10
KFLX	George Roy Clough	Galveston, Texas	1250	240	10
KFLY	Fargo Radio Supply Co.	Fargo, N. D.	1300	231	20
KFLZ	Atlantic Automobile Co.	Atlantic, Iowa	1100	273	100
KFMB	Christian Churches of Little Rock	Little Rock, Ark.	1180	254	50
KFMQ	Univ. of Arkansas	Fayetteville, Ark.	1140	263	100
KFMR	Morningside College	Sioux City, Iowa	1150	261	10
KFMS	Freimuth Dept. Store	Duluth, Minn.	1090	275	100
KFMT	Dr. Geo. W. Young	Minneapolis, Minn.	1300	231	5
KFMU	Stevens Bros	San Marcos, Texas	1250	240	20
KFMW	M. G. Sateren	Houghton, Mich.	1130	265	50
KFMX	Carleton College	Northfield, Minn.	1060	283	500
KFMY	Boy Scouts of America, Long Beach Dist. Council	Long Beach, Calif.	1310	229	20
KFMZ	Roswell Broadcasting Club	Roswell, N. M.	1200	250	100
KFNC	Alonzo Monk, Jr.	Corsicana, Tex.	1280	234	20
KFNF	Henry Field Seed Co.	Shenandoah, Iowa	1130	266	500
KFNG	Wooten's Radio Shop	Coldwater, Miss.	1180	254	10
KFNH	State Teachers College	Springfield, Mo.	1270	236	20
KFNJ	Warrensburg Elec. Shop.	Warrensburg, Mo.	1280	234	50
KFNL	Radio Broadcast Ass'n	Paso Robles, Calif.	1250	240	10
KFNV	L. A. Drake Battery & Radio Supply Shop	Santa Rosa, Calif.	1280	234	5
KFNX	Peabody Radio Service	Peabody, Kansas	1250	240	10
KFNY	Montana Phonograph Co.	Helena, Mont.	1150	261	5
KFNZ	Royal Radio Company	Burlingame, Calif.	1300	231	10
KFOA*	The Rhodes Co.	Seattle, Wash.	660	454	500
KFOC	First Christian Church	Whittier, Calif.	1270	236	100
KFOD	The Radio Shop	Wallace, Idaho	1340	224	10
KFOD	Vern Peters	Wallace, Idaho	1340	224	10
KFOF	Rohrer Electric Co.	Marshfield, Ore.	1250	240	10
KFOH	The Radio Bungalow	Portland, Ore	1060	283	15
KFOJ	Moberly H. S. Radio Club.	Moberly, Mo.	1220	246	5
KFOL	Leslie M. Schafbuch	Marengo, Iowa	1280	234	10
KFON	Echophone Radio Shop	Long Beach, Calif.	1280	234	100
KFOO	Latter Day Saints Univ.	Salt Lake City, Utah	1150	261	10
KFOP	Willson Construc. Co.	Dallas, Texas	1120	268	100
KFOQ	O. William Chancellor	Galveston, Texas	1250	240	50
KFOR	David City Tire & Elec. Co.	David City, Nebr.	1330	225	10
KFOT	College Hill Radio Club.	Wichita, Kans.	1300	231	50
KFOU	Hommel Mfg. Co	Richmond, Cal.	1180	254	160
KFOV	Davis Electrical Corp.	Sioux City, Iowa	1280	234	10
KFOX	Board of Ed., Tech. H. S.	Omaha, Nebr.	1210	218	100
KFOY	Beacon Radio Service	St. Paul, Minn.	1350	226	50
KFOZ	Leon Hudson Real Estate Co.	Ft. Smith, Ark.	1290	233	20
KFPB	Edwin J. Brown	Seattle, Wash.	1340	224	15
KFPG	Garretson & Dennis	Los Angeles	1260	238	100
KFPH	H. C. Mailander	Salt Lake City, Utah	1240	242	50
KFPL	C. C. Baxter	Dublin, Texas	1240	242	20
KFPM	The New Furniture Co.	Greenville, Texas	1240	242	10
KFPN	Missouri National Guard	Jefferson City, Mo.	1240	242	10
KFPO	Colorado National Guard	Denver, Colo	1300	231	500
KFPP	G. & G. Radio & Elec. Co.	Olympia, Wash.	1270	236	20
KFPQ	Clifford M. Esler	Denison, Texas	1300	231	10
KFPR	Los Angeles. Co. Forestry Dept.	Los Angeles, Cal.	1300	231	500

*This Company also operates station KDZE

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFPS	C. A. Ross Motor Service Co.	Casper, Wyo.	1240	242	10
KFPT	Cope & Johnson Co.	Salt Lake City, Utah	1120	268	500
KFPV	Heintz & Kohlmoos, Inc.	San Francisco, Cal.	1270	236	50
KFPX	First Presbyterian Church.	Pine Bluff, Ark.	1240	242	100
KFPY	Symons Investment Co.	Spokane, Wash.	1060	283	100
KFQA	The Principia	St. Louis, Mo.	1150	261	50
KFQB	The Searchlight Pub. Co.	Fort Worth, Texas.	1180	254	100
KFQC	Kidd Bros. Radio Shop.	Taft, Calif.	1320	227	100
KFQD	Chovin Supply Co.	Anchorage, Alaska.	1070	280	100
KFQE	Dickenson-Henry Radio Laboratories	Colo. Springs, Colo.	1340	224	5
KFQF	Donald A. Boult	Minneapolis, Minn.	1340	224	10
KFQG	So. Calif. Radio Ass'n.	Los Angeles, Calif.	1330	226	100
KFQH	Albert Sherman	Hillsbourgh, Calif.	1300	231	50
KFQI	Thos. H. Ince Corp.	Culver City, Calif.	1280	234	100
KFQJ	Harbour-Longmire Co.	Oklahoma City, Okla	1270	236	50
KFQK	Democrat Leader	Fayette, Mo.	1270	236	10
KFQL	Oklahoma Free State Fair Association	Muskogee, Okla.	1190	252	20
KFSG	Echo Park Evangelistic Ass'n	Los Angeles, Calif.	1280	234	500
KGB	Tacoma Daily Ledger	Tacoma, Wash.	1190	252	50
KGG	Hallock & Watson Radio Service	Portland, Ore.	833	360	50
KGN	Northwestern Rad. Mfg. Co.	Portland, Ore.	833	360	15
KGO	General Elec. Co.	Oakland, Calif.	960	312	1000
KGU	Marion A. Mulrony	Honolulu, Hawaii	833	360	250
KGW	Oregonian Publishing Co.	Porland, Ore.	610	492	500
KGY	St. Martins College	Lacey, Wash.	1160	259	5
KHJ	Times-Mirror Co.	Los Angeles, Cal.	760	395	500
KHQ	Louis Wasmer	Seattle, Wash.	833	360	100
KJQ	C. O. Gould	Stockton, Calif.	833	360	5
KJR	Northwest Radio Serv. Co.	Seattle, Wash.	1060	283	50
KJS	Bible Inst. of Los Angeles	Los Angeles, Calif.	833	360	750
KLS	Warner Bros.	Oakland, Calif.	833	360	250
KLX	Tribune Publishing Co.	Oakland, Calif.	590	508	500
KLZ	Reynolds Radio Co., Inc.	Denver, Colo.	1060	283	500
KMJ	San Joaquin Lt.&P'r Corp.	Fresno, Calif.	1210	248	50
KMO	Love Electric Co.	Tacoma, Wash.	833	360	10
KNT	Walter Hemrich	Kukak Bay, Alaska.	1140	263	100
KNX	Elec. Light Supply Co.	Los Angeles, Calif.	833	360	100
KOB	N. Mex. College of Agriculture and Mechanic Arts.	State College, N.Mex	833	360	500
KOP	Detroit Police Dept.	Detroit, Mich.	1050	286	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	710	422	500
KQP	Apple City Radio Club	Hood River, Ore.	833	360	10
KQV	Doubleday-HillElectricCo.	Pittsburgh, Pa.	1110	270	500
KQW	Charles D. Herrold	San Jose, Calif.	833	360	50
KRE	Berkeley Daily Gazette	Berkeley, Calif.	1090	275	50
KSD	Post-Dispatch	St. Louis, Mo.	550	545	500
KTW	First Presbyterian Church.	Seattle, Wash.	833	360	750
KUO	Examiner Printing Co.	San Francisco, Calif.	833	360	150
KUY	Coast Radio Co., Inc.	El Monte, Calif.	1170	256	50
KWG	Portable Wireless Telephone Co.	Stockton, Calif.	833	360	100
KWH	Los Angeles Examiner	Los Angeles, Calif.	833	360	500
KYQ	Electric Shop	Honolulu, Hawaii	1110	270	100
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	560	535	1000
KZM	Preston D. Allen	Oakland, Calif.	833	360	100
KZV	Wenatchee Battery & Motor Co.	Wenatchee, Wash.	833	360	50
WAAB	Valdemar Jensen	New Orleans, La.	1120	268	100
WAAC	Tulane University	New Orleans, La.	833	360	100

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Oscill. Watts
WAAD	Ohio Mechanics Institute	Cincinnati, Ohio	833	360	25
WAAF	Chicago Daily Drovers Journal	Chicago, Ill.	1050	286	200
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAN	University of Missouri	Columbia, Mo.	1180	254	50
WAAW	Omaha Grain Exchange	Omaha, Nebr.	833	360	500
WABA	Lake Forest College	Lake Forest, Ill.	1130	265	100
WABB	Harrisburg Sporting Goods Co.	Harrisburg, Pa.	1130	266	10
WABD	Parker High School	Dayton, Ohio	1060	283	5
WABE	Y. M. C. A.	Washington, D. C.	1060	283	100
WABG	Arnold Edwards Piano Co.	Jacksonville, Fla.	10[illegible]0	275	10
WABH	Lake Shore Tire Co.	Sandusky, Ohio	1250	240	10
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	100
WABL	Connecticut Agri. College	Storrs, Conn.	1060	283	100
WABM	F. E. Doherty	Saginaw, Mich.	1180	254	100
WABN	Ott Radio, Inc.	La Crosse, Wis.	1230	244	250
WABO	Lake Ave. Baptist Church	Rochester, N. Y.	1060	283	10
WABP	Robert Frederick Weinig	Dover, Ohio	1130	265	100
WABQ	Haverford College Radio Club	Haverford, Penna.	1150	261	50
WABR	Scott High School (J.W.B. Foley)	Toledo, Ohio	1110	270	50
WABS	Essex Mfg. Co.	Newark, N. J.	1230	244	50
WABT	Holliday-Hall, Radio Engrs.	Washington, Penna.	11[illegible]0	252	100
WABU	Victor Talking Machine Co.	Camden, N. J.	1330	225	50
WABV	John H. DeWitt, Jr.	Nashville, Tenn.	1140	263	20
WABW	The College of Wooster, Physics Dept.	Wooster, Ohio	1280	234	20
WABX	Henry B. Joy	(near) Mt. Clemens, Mich.	1110	270	150
WABY	John Magaldi, Jr.	Philadelphia, Pa.	1240	242	50
WABZ	Coliseum Place Baptist Church	New Orleans, La.	1140	263	50
WBAA	Purdue University	West Lafayette, Ind.	833	360	250
WBAH	The Dayton Co.	Minneapolis, Minn.	720	416	500
WBAK	Penn. State Dept. of Police	Harrisburg, Pa.	750	400	500
WBAN	Wireless Phone Corp.	Paterson, N. J.	1230	244	100
WBAO	James Millikin University	Decatur, Ill.	833	360	50
WBAP	The Ft. Worth Star Telegram	Fort Worth, Tex.	630	476	750
WBAV	Erner & Hopkins Co.	Columbus, Ohio	770	389	500
WBAX	John H. Stenger, Jr.	Wilkes-Barre, Pa.	833	360	20
WBAY	Western Elec. Co.	New York City, N.Y.	610	4[illegible]2	500
WBBA	Newark Radio Lab.	Newark, Ohio	1250	240	10
WBBD	Barbey Battery Service	Reading, Pa.	1260	2[illegible]8	10
WBBE	Alfred R. Marcey	Syracuse, N. Y.	1220	246	10
WBBF	Georgia School of Technology	Atlanta, Ga.	1110	270	500
WBBG	Irving Vermilya	Mattapoisett, Mass.	1210	248	500
WBBH	J. Irving Bell	Port Huron, Mich.	1220	246	50
WBBJ	Neel Elec. Co. (P. E. Neel)	W. Palm Beach, Fla.	1160	258	50
WBBL	Grace Covenant Church	Richmond, Va.	1060	283	5
WBBM	Frank Atlass Produce Co.	Lincoln, Ill.	13[illegible]0	225	200
WBBN	A. B. Blake	Wilmington, N. C.	10[illegible]0	275	10
WBBO	Michigan Limestone & Chem. Co.	Rodgers, Mich.	1200	250	500
WBBP	Petoskey High School	Petoskey, Mich.	1220	246	10
WBBQ	Frank Crook	Pawtucket, R. I.	11[illegible]0	252	100
WBBR	Peoples Pulpit Ass'n	Rossville, N. Y.	11[illegible]0	273	500
WBBS	First Baptist Church	New Orleans, La.	1200	250	100
WBBT	Lloyd Bros.	Philadelphia, Pa.	1280	234	5
WBBU	Jenks Motor Sales Co.	Monmouth, Ill.	1340	224	10
WBBV	Johnstown Radio Co.	Johnstown, Pa.	1210	2[illegible]8	5

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WBBW	Ruffner Junior H. S.	Norfolk, Va.	1350	222	50
WBBY	Washington Light Infantry Co. B, 118th Inf.	Charleston, S. C.	1120	268	10
WBBZ	Noble B. Watson	Indianapolis, Ind.	1320	227	50
WBL	T. & H. Radio Co.	Anthony, Kans.	1150	261	100
WBR	Penna. State Police	Butler, Penna.	1050	286	250
WBS	D. W. May (Inc.)	Newark, N. J.	833	360	10
WBT	Southern Radio Corp.	Charlotte, N. C.	833	360	500
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	890	337	1000
WCAD	St. Lawrence University	Canton, N. Y.	1070	280	250
WCAE	Kaufman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCAG	Clyde R. Randall	New Orleans, La.	1120	268	100
WCAH	Entrekin Electric Co.	Columbus, Ohio	1050	286	100
WCAJ	Nebraska Wesleyan Univ.	Univ. Place, Nebr.	833	360	500
WCAK	Alfred P. Daniel	Houston, Texas	1140	263	10
WCAL	St. Olaf College, Physics Dept.	Northfield, Minn.	833	360	500
WCAM	Villanova College	Villanova, Pa.	833	360	150
WCAO	Sanders & Stayman Co.	Baltimore, Md.	833	360	50
WCAP	Chesapeake & Potomac Telphone Co.	Washington, D. C.	640	469	500
WCAR	The Southern Radio Corp. of Texas	San Antonio, Tex.	833	360	100
WCAS	Dunwoody Industr. Inst.	Minneapolis, Minn.	1070	280	100
WCAT	S. Dak. State Sch. of Mines	Rapid City, S. Dak.	1250	240	50
WCAU	Durham & Co.	Philadelphia, Pa.	1050	286	250
WCAV	J. C. Dice Electric Co.	Little Rock, Ark.	833	360	10
WCAX	University of Vermont	Burlington, Vt.	833	360	50
WCAY	Milwaukee Civic Broadcasting Ass'n., Inc.	Milwaukee, Wis.	1130	266	250
WCAZ	Carthage College	Carthage, Ill.	1220	246	50
WCBA	Chas. W. Heimbach	Allentown, Pa.	1070	280	5
WCBC	Univ. of Michigan	Ann Arbor, Mich.	1070	280	200
WCBD	Wilbur Glenn Voliva	Zion, Ill.	870	345	500
WCBE	Uhalt Radio Co.	New Orleans, La.	1140	263	5
WCBF	Paul J. Miller	Pittsburgh, Pa.	1270	236	50
WCBG	Howard S. Williams	Pascagoula, Miss. (Portable)	1120	268	10
WCBH	Univ. of Mississippi	(near) Oxford, Miss.	1240	242	20
WCBI	Nicell, Duncan & Rush	Bemis, Tenn.	1250	240	50
WCBJ	J. C. Maus	Jennings, La.	1230	244	10
WCBK	E. Richard Hall	St. Petersburg, Fla.	1130	266	500
WCBL	Northern Radio Mfg. Co.	Houlton, Me.	1070	280	50
WCBM	Charles Schwarz	Baltimore, Md.	1310	229	50
WCBN	James P. Boland	Ft. Benjamim Harrison, Ind.	1130	266	50
WCBO	The Radio Shop, Inc.	Memphis, Tenn.	1200	250	20
WCBQ	First Baptist Church	Nashville, Tenn.	1270	236	100
WCBR	Charles H. Messter	Providence, R. I. (Portable)	1220	246	5
WCBT	Clark Univ. Collegiate Dept	Worcester, Mass.	1260	238	250
WCBU	Arnold Wireless Supply Co.	Arnold, Pa.	1180	254	50
WCBV	Tullahoma Radio Club	Tullahoma, Tenn.	1190	252	10
WCBW	G. P. Rankin, Jr. & M. Solomon	Macon, Ga.	1330	226	10
WCBX	Radio Shop of Newark	Newark, N. J.	1290	232	10
WCBY	The Forks Elec. Shop	Buck Hill Falls, Pa.	1120	268	10
WCBZ	Coppotelli Bros. Music House	Chicago Heights, Ill	1210	248	50
WCK	Stix, Baer & Fuller Co.	St. Louis, Mo.	833	360	100
WCM	University of Texas	Austin, Tex.	833	360	500
WCX	Detroit Free Press	Detroit, Mich.	580	517	500
WDAE	Tampa Daily Times	Tampa, Fla.	833	360	250
WDAF	The Kansas City Star	Kansas City, Mo.	730	411	500

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WDAG	J. L. Martin	Amarillo, Tex.	1140	263	100
WDAH	Trinity Methodist Church	El Paso, Tex.	1120	268	100
WDAK	Hartford Courant	Hartford, Conn.	1150	261	100
WDAO	Automotive Electric Co.	Dallas, Tex.	833	360	50
WDAP	Drake Hotel	Chicago, Ill	833	360	1000
WDAR	Lit Brothers	Philadelphia, Pa.	760	395	500
WDAS	Samuel A. Waite	Worcester, Mass.	833	360	10
WDAU	Slocum & Kilburn	New Bedford, Mass.	833	360	100
WDAY	Radio Equip. Corp.	Fargo, N. Dak.	1230	244	50
WDBA	Fred Ray	Columbus, Ga.	1270	236	20
WDBB	A. H. Waite & Co., Inc.	Taunton, Mass.	1310	229	10
WDBC	Kirk, Johnson & Co., Inc.	Lancaster, Pa.	1160	259	50
WDBD	Herman E. Burns	Martinsburg, W. Va	1120	268	5
WDBE	Gilham-Schoen Elec. Co.	Atlanta, Ga.	1190	252	10
WDBF	Robert G. Phillips	Youngstown, Ohio	1220	246	50
WDBH	C. T. Scherer Co.	Worcester, Mass.	1120	268	100
WDBI	Radio Specialty Co.	St. Petersburg, Fla.	1330	225	10
WDBJ	Richardson & Wayland Elec Corp.	Roanoke, Va.	1310	229	20
WDBK	M. F. Bros. Furniture Hdw. & Radio Co.	Cleveland, Ohio	1210	248	100
WDBL	Wisconsin Dept. of Markets	Stevens Points, Wis.	1080	278	500
WDBN	Electric & Power Co.	Bangor, Me.	1190	252	5
WDBO	Rollins College, Inc.	Winter Park, Fla.	1250	240	50
WDBP	Superior State Normal School	Superior, Wis.	1150	261	50
WDBQ	Morton Radio Supply Co.	Salem, N. J.	1280	234	10
WDBR	Tremont Temple Baptist Church	Boston, Mass.	1170	256	100
WDBS	The S. M. K. Radio Corp.	Dayton, Ohio	1060	283	5
WDBT	Taylor's Book Store	Hattiesburg, Miss.	1270	236	10
WDBU	Somerset Radio Co.	Skowhegan, Maine.	1160	258	10
WDBV	The Quimby Enterprises, Strand Theatre	Fort Wayne, Ind.	1160	258	100
WDBW	The Radio Den	Columbia, Tenn.	1120	268	20
WDM	Grace Church of the Covenant	Washington, D. C.	1280	234	50
WDZ	James L. Bush	Tuscola, Ill.	1080	278	10
WEAA	Frank D. Fallain & (Police Dept.)	Flint, Mich.	1070	280	10
WEAF	American Tel. & Tel. Co.	New York City, N.Y.	610	492	1000
WEAH	Wichita Board of Trade	Wichita, Kans.	1070	280	100
WEAI	Cornell University	Ithaca, N. Y.	1050	286	500
WEAJ	Univ. of South Dakota	Vermillion, S. Dak.	1060	283	100
WEAM	Borough of No. Plainfield	N. Plainfield, N. J.	1050	286	150
WEAN	The Shepard Company	Providence, R. I.	1100	273	100
WEAO	Ohio State University	Columbus, Ohio	833	360	500
WEAP	Mobile Radio Co., Inc.	Mobile, Ala.	833	360	100
WEAR	Evening News Pub. Co.	Baltimore, Md.	1150	261	50
WEBH	Edgewater Beach Hotel Co.	Chicago, Ill.	810	370	500
WEBP	E. B. Peddicord	New Orleans, La.	1240	242	10
WEAU	Davidson Bros. Co.	Sioux City, Iowa.	833	360	100
WEAY	Iris Theater	Houston, Tex.	833	360	500
WEB	Benwood Co., Inc.	St. Louis, Mo.	1100	273	500
WEV	Hurlburt-Still Electrical Co.	Houston, Tex.	833	360	100
WEW	St. Louis University	St. Louis, Mo.	1070	280	100
WFAA	Dallas News & Dallas Jour.	Dallas, Texas	630	476	500
WFAB	Carl F. Woese	Syracuse, N. Y.	1280	234	100
WFAF	H. C. Spratley Co.	Poughkeepsie, N. Y.	1100	273	20
WFAH	Electric Supply Co.	Port Arthur, Tex.	1270	236	50
WFAJ	Hi-Grade Wireless Instrument Co.	Asheville, N. C.	833	360	50
WFAM	Times Publishing Co.	St. Cloud, Minn.	833	360	20
WFAN	Hutchinson Elec. Serv. Co.	Hutchinson, Minn.	833	360	100

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WFAQ	Missouri Wesleyan College	Cameron, Mo.	833	360	10
WFAT	The New Columbus College	Sioux Falls, S. D.	1160	258	50
WFAV	University of Nebraska	Lincoln, Nebr.	1090	275	500
WFBW	Ainsworth-Gates Radio Co.	Cincinnati, Ohio	970	309	750
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGAL	Lancaster Electric Supply & Construction Co.	Lancaster, Pa.	1210	248	50
WGAN	Cecil E. Lloyd	Pensacola, Fla.	833	360	50
WGAQ	Glenwood Radio Corp.	Shreveport, La.	1190	252	150
WGAW	Ernest C. Albright	Altoona, Pa.	1150	261	100
WGAZ	South Bend Tribune	South Bend, Ind.	833	360	250
WGI	Am. Rad. & Research Corp.	Medford Hillside, Mass.	833	360	100
WGL	Thos. F. J. Howlett	Philadelphia, Pa.	833	360	250
WGR	Federal Tel. & Tel. Co.	Buffalo, N. Y.	940	319	750
WGV	Interstate Elec. Co.	New Orleans, La.	1240	242	100
WGY	General Electric Co.	Schenectady, N. Y.	790	380	1000
WHA	University of Wisconsin	Madison, Wis.	833	360	500
WHAA	State Univ. of Iowa	Iowa City, Iowa	620	484	500
WHAB	The Clark W. Thompson Co.	Galveston, Tex.	833	360	200
WHAD	Marquette University	Milwaukee, Wis.	1070	280	100
WHAG	Univ. of Cincinnati	Cincinnati, Ohio	1350	222	200
WHAH	Hafer Supply Co.	Joplin, Mo.	1060	283	250
WHAK	Roberts Hardware Co.	Clarksburg, W. Va.	1260	238	15
WHAM	Univ. of Rochester	Rochester, N. Y.	1060	283	100
WHAP	Otto & Kuhns	Decatur, Ill.	833	360	50
WHAR	Paramount Radio & Elec. Co.	Atlantic City, N. J.	1300	231	10
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAV	Wilmington Elec. Spec. Co.	Wilmington, Del.	833	360	50
WHAZ	Rensselaer Polytechnic Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Automotive and Electrical School	Kansas City, Mo.	730	411	500
WHK	The Radiovox Co.	Cleveland, Ohio	1060	283	100
WHN	Loew's State Theatre Studio	New York City, N.Y.	833	360	500
WHO	Bankers Life Co.	Des Moines, Ia.	570	526	500
WIAB	Joslyn Automobile Co.	Rockford, Ill.	1190	252	50
WIAC	Galveston Tribune	Galveston, Tex.	833	360	100
WIAD	Howard R. Miller	Philadelphia, Pa.	1180	254	100
WIAF	Gustav A. De Cortin	New Orleans, La.	1280	234	10
WIAI	The Heer Stores Co.	Springfield, Mo.	1190	252	20
WIAJ	Fox River Valley Radio Supply Co.	Neenah, Wis.	1340	224	20
WIAK	Journal-Stockman Co.	Omaha, Nebr.	1080	278	250
WIAO	School of Eng. of Milwaukee	Milwaukee, Wis.	1220	246	100
WIAQ	Chronicle Pub. Co.	Marion, Ind.	1330	225	10
WIAS	Home Electric Co.	Burlington, Iowa	1060	283	100
WIAU	Amer. Trust & Savings Bk.	Le Mars, Iowa	833	360	20
WIAY	Woodward & Lathrop	Washington, D. C.	1100	273	100
WIK	K. & L. Elec. Co.	McKeesport, Pa.	1280	234	100
WIL	Continental Elec. Sup. Co.	Washington, D. C.	833	360	5
WIP	Gimbel Brothers	Philadelphia, Pa.	590	508	500
WJAB	American Elec. Co.	Lincoln, Neb.	1310	229	100
WJAD	Frank P. Jackson	Waco, Tex.	833	360	150
WJAG	The Norfolk Daily News	Norfolk, Nebr.	1060	283	250
WJAK	Clifford L. White	Greentown, Ind.	1180	254	30
WJAM	D. M. Perham	Cedar Rapids, Iowa	1120	268	20
WJAN	Peoria Star Co.	Peoria, Ill.	1070	280	100
WJAQ	Capper Publications	Topeka, Kans.	833	360	100
WJAR	The Outlet Co.	Providence, R. I.	833	360	500
WJAS	Pittsburgh Radio Sup. Hse.	Pittsburgh, Pa.	1200	250	500
WJAT	Kelley-Vawter Jewelry Co.	Marshall, Mo.	833	360	10
WJAX	Union Trust Co.	Cleveland, Ohio	770	390	500

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WJAZ	Chicago Radio Lab	Chicago Ill	1120	268	20
WJD	Denison Univ	Granville, Ohio	1310	229	10
WJX	DeForest Rad. Tel. & Tel. Co.	Jersey City, N. J.	833	360	500
WJY	Radio Corp. of America	New York, N. Y.	740	405	500
WJZ	Radio Corp. of America	New York, N. Y.	660	454	500
WKAA	H. F. Parr	Cedar Rapids, Iowa	1120	268	50
WKAD	Charles Looff	East Providence, R.I.	1250	240	10
WKAF	W. S. Radio Supply Co.	Wichita Falls, Texas	833	360	100
WKAN	United Battery Serv. Co.	Montgomery, Ala.	1330	225	20
WKAP	Dutee W. Flint	Cranston, R. I.	833	360	50
WKAQ	Radio Corp. of P. R.	San Juan, Porto Rico	833	360	500
WKAR	Mich. Agri. College	East Lansing, Mich.	1070	280	500
WKAV	The Laconia Radio Club	Laconia, N. H.	1180	254	50
WKAY	Brenau College	Gainesville, Ga.	1070	280	10
WKBF	Dutee Wilcox Flint	Cranston, R. I	1050	286	500
WKY	WKY Radio Shop	OklahomaCity, Okla.	833	360	100
WLAG	Cutting & Washington Radio Corp.	Minneapolis, Minn.	720	416	500
WLAH	Samuel Woodworth	Syracuse, N. Y.	1280	234	100
WLAJ	Waco Electric Supply Co.	Waco, Texas	833	360	50
WLAK	Vermont Farm Mach. Co.	Bellows Falls, Vt.	833	360	500
WLAL	Naylor Elec. Co.	Tulsa, Okla.	833	360	100
WLAP	W. V. Jordan	Louisville, Ky.	833	360	15
WLAQ	A. E. Schilling	Kalamazoo, Mich.	1060	283	10
WLAV	The Electric Shop, Inc.	Pensacola, Fla.	1180	254	20
WLAW	N. Y. Police Dept.	New York City, N.Y.	833	360	500
WLAX	Greencastle Community Broadcasting Station	Greencastle, Ind.	1300	231	10
WLB	Univ. of Minnesota	Minneapolis, Minn.	833	360	5
WLBL	Wisconsin Dept. of Markets	Stevens Point, Wis.	1080	278	500
WLS	Sears, Roebuck & Co.	Chicago, Ill.	870	345	500
WLW	Crosley Radio Corp.	Cincinnati, Ohio.	970	309	500
WMAB	Radio Supply Co.	Oklahoma City, Okla	833	360	100
WMAC	Clive B. Meredith	Cazenovia, N. Y.	1150	261	200
WMAF	Round Hills Radio Corp.	S. Dartmouth, Mass.	833	360	500
WMAH	General Supply Co.	Lincoln, Nebr.	1180	254	100
WMAJ	Daily Drovers Telegram.	Kansas City, Mo.	1090	275	250
WMAK	Norton Laboratories, Inc.	Lockport, N. Y.	1100	273	500
WMAL	Trenton Hardware Co.	Trenton, N. J.	1170	256	50
WMAN	First Baptist Church	Columbus, Ohio.	1050	286	10
WMAP	Utility Battery Service, Inc.	Easton, Pa.	1220	246	50
WMAQ	Chicago Daily News	Chicago, Ill.	670	448	500
WMAV	Alabama Polytechnic Inst.	Auburn, Ala.	1200	250	500
WMAY	Kingshighway Pres. Church	St. Louis, Mo.	1070	280	100
WMAZ	Mercer University	Macon, Ga	1150	261	100
WMC	The Commercial Pub. Co.	Memphis, Tenn.	600	500	500
WMU	Doubleday-Hill Elec. Co.	Washington, D. C.	1150	261	100
WNAC	Shepard Stores	Boston, Mass.	1080	278	100
WNAD	Univ. of Oklahoma	Norman, Okla.	833	360	50
WNAL	R. J. Rockwell	Omaha, Nebr.	1130	265	20
WNAN	Syracuse Radio Tel. Co.	Syracuse, N. Y.	1050	286	200
WNAP	Wittenberg College	Springfield, Ohio	1090	275	100
WNAQ	Charleston Radio Elec. Co.	Charleston, S. C.	833	360	20
WNAR	C. C. Rhodes	Butler, Mo.	1300	231	20
WNAT	Lenning Bros. Co.	Philadelphia, Pa.	833	360	100
WNAV	Peoples Te. & Tel. Co.	Knoxville, Tenn.	1270	236	500
WNAW	Henry Kunzman	Fort Monroe, Va.	833	360	10
WNAX	Dakota Radio App. Co.	Yankton, S. D.	1230	244	100
WNJ	Shotten Radio Mfg. Co.	Albany, N. Y.	833	360	25
WOAC	Pagan Organ Co.	Lima, Ohio	1130	265	150
WOAD	Friday Battery & Elec. Co.	Sigourney, Iowa	833	360	20
WOAE	Midland College	Fremont, Nebr.	833	360	20
WOAF	Tyler Commercial College	Tyler, Texas	833	360	20

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WOAG	Apollo Theatre	Belvidere, Ill.	1100	273	100
WOAH	Palmetto Radio Shop	Charleston, S. C.	833	360	100
WOAI	Southern Equip. Co.	San Antonio, Texas	780	384	500
WOAN	James D. Vaughan	Lawrenceburg, Tenn.	833	360	200
WOAO	Lyradion Mfg. Co.	Mishawaka, Ind.	833	360	50
WOAP	Kalamazoo College	Kalamazoo, Mich.	1160	259	100
WOAR	Henry P. Lundskow	Kenosha, Wis.	1310	229	50
WOAT	Boyd M. Hamp	Wilmington, Del.	833	360	50
WOAV	Pennsylvania Nat. Guard	Erie, Pa.	1240	242	50
WOAW	Sovereign Camp, Woodmen of the World	Omaha, Nebr.	570	526	500
WOAX	Franklyn J. Wolff	Trenton, N. J.	1250	240	500
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa	620	484	500
WOI	Iowa State College	Ames, Iowa	833	360	500
WOK	Pine Bluff Co.	Arkadelphia, Ark.	1130	265	250
WOO	John Wanamaker	Philadelphia, Pa.	590	508	500
WOQ	Western Radio Co.	Kansas City, Mo.	833	360	500
WOR	L. Bamberger & Co.	Newark, N. J.	740	405	500
WOS	Mo. State Marketing Bur.	Jefferson City, Mo.	680	441	500
WPAB	Pennsylvania State College	State College, Pa.	1060	283	500
WPAC	Donaldson Radio Co.	Okmulgee, Okla.	833	360	200
WPAJ	Doolittle Radio Corp.	New Haven, Conn.	1120	268	100
WPAK	Agri. College of N. Dakota	Fargo, N. Dakota	833	360	50
WPAL	Avery & Loeb Elec. Co.	Columbus, Ohio	1050	286	500
WPAM	Auerbach & Geuttel	Topeka, Kans.	833	360	100
WPAP	Theodore D. Phillips	Winchester, Ky.	833	360	35
WPAR	Ward Battery & Radio Co.	Beloit, Kansas	1270	236	10
WPAT	Saint Patrick's Cathedral	El Paso, Texas	833	360	20
WPAU	Concordia College	Moorhead, Minn.	833	360	20
WPAZ	Dr. John R. Koch	Charleston, W. Va.	1100	273	10
WQAA	Horace A. Beale, Jr.	Parkesburg, Pa.	833	360	500
WQAC	Gish Radio Service	Amarillo, Tex.	1280	234	100
WQAE	Moore Radio News Station	Springfield, Vt.	1090	275	50
WQAF	Sandusky Register	Sandusky, Ohio	1250	240	5
WQAL	Coles County Tel. & Tel.	Mattoon, Ill.	1160	259	10
WQAM	Electrical Equip. Co.	Miami, Fla.	1060	283	100
WQAN	Scranton Times	Scranton, Pa.	1070	280	50
WQAO	Calvary Baptist Church	New York City, N.Y.	833	360	100
WQAQ	Abilene Daily Reporter (West Texas Radio Co.)	Abilene, Tex.	833	360	50
WQAS	Prince-Walter Co.	Lowell, Mass.	1130	265	100
WQAW	Catholic Univ. of Amer.	Washington, D. C.	1270	236	5
WQAX	Radio Equip. Co.	Peoria, Ill.	1210	248	100
WQJ	Calumet Baking Powder Co	Chicago, Ill.	670	448	500
WRAA	Rice Institute	Houston, Tex.	833	360	200
WRAF	Radio Club, Inc.	Laporte, Ind.	1340	224	10
WRAH	Stanley N. Read	Providence, R. I.	1300	231	15
WRAL	Northern States Power Co.	St. Croix Falls, Wis.	1210	248	10
WRAM	Lombard College	Galesburg, Ill.	1230	244	100
WRAN	Black Hawk Elec. Co.	Waterloo, Iowa	1270	236	10
WRAO	St. Louis Radio Service Co.	St. Louis, Mo.	833	360	10
WRAV	Antioch College	Yellow Springs, O.	1240	242	100
WRAW	Avenue Radio Shop	Reading, Pa.	1260	238	10
WRAX	Flexon's Garage	Gloucester City, N.J.	1120	268	100
WRAY	Radio Sales Corp.	Scranton, Pa.	1070	280	10
WRBC	Immanuel Lutheran Church	Valparaiso, Ind.	1080	278	500
WRC	Radio Corp. of America	Washington, D. C.	640	469	500
WRK	Doron Bros. Elec. Co.	Hamilton, Ohio	833	360	200
WRL	Union College	Schenectady, N. Y.	833	360	500
WRM	Univ. of Illinois	Urbana, Ill.	833	360	500
WRR	City of Dallas, Police and Fire Signal Dept.	Dallas, Texas	833	360	30
WRW	Tarrytown Radio Research	Tarrytown, N. Y.	1100	273	150
WSAB	Southeast Missouri State Teachers College	Cape Girardeau, Mo.	833	360	100

Active Broadcasting Stations, June 15, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Kil. Watts
WSAC	Clemson Agri. College	Clemson College, S.C.	833	360	500
WSAD	J. A. Foster Co.	Providence, R. I.	1150	261	150
WSAG	L. V. Davis & G. Prestman, Sr	St. Petersburg, Fla.	1230	244	10
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	970	309	500
WSAJ	Grove City College	Grove City, Pa.	833	360	250
WSAN	Allentown Radio Club	Allentown, Pa.	1310	229	10
WSAP	Seventh Day Adventist Church	New York, N. Y.	1140	263	250
WSAR	Doughty & Welch Elec. Co	Fall River, Mass.	1180	254	10
WSAT	Donohoo-Ware Hardware Co.	Plainview, Texas	1120	268	20
WSAU	Camp Marienfeld	Chesham, N. H.	1310	229	10
WSAV	Clifford W. Vick Radio Constr. Co.	Houston, Tex	833	360	100
WSAW	John J. Long, Jr.	Canandaigua, N. Y.	1090	275	5
WSAY	Irving Austin, Rep. Port Chester Cham. of Com.	Port Chester, N. Y.	1290	232	100
WSAZ	Chase Electric Shop	Pomeroy, Ohio	1160	258	50
WSB	Atlanta Journal	Atlanta, Ga.	700	428	500
WSL	J. & M. Electric Co.	Utica, N. Y.	1100	273	100
WSY	Alabama Power Co.	Birmingham, Ala.	833	360	500
WTAB	Fall River Daily Herald Co.	Fall River, Mass.	1130	266	100
WTAC	Penn Traffic Co.	Johnstown, Pa.	1090	275	100
WTAF	Louis J. Gallo	New Orleans, La.	1120	268	10
WTAG	Kern Music Co.	Providence, R. I.	1160	258	10
WTAH	Carmen Ferro	Belvidere, Ill.	1270	236	10
WTAJ	The Radio Shop	Portland, Maine	1270	236	10
WTAL	Toledo Radio & Elec. Co.	Toledo, Ohio	1190	252	10
WTAM	The Willard Stor. Batt. Co.	Cleveland, Ohio	770	389	1500
WTAP	Cambridge Radio & Elec. Co.	Cambridge, Ill.	1230	242	50
WTAQ	S. H. Van Gorden & Son	Osseo, Wis.	1180	254	100
WTAR	Reliance Elec. Co.	Norfolk, Va.	1070	280	100
WTAS	Chas. E. Erbstein	Elgin, Ill.	1050	286	500
WTAT	The Edison Elec. Illuminating Co. of Boston	Boston, Mass. (Portable)	1220	246	100
WTAU	Ruegy Battey & Elec. Co.	Tecumseh, Nebr.	1200	252	10
WTAW	Agri. & Mech. Col. of Tex.	College Station, Tex.	1070	280	250
WTAX	Williams Hardware Co.	Streator, Ill.	1300	231	50
WTAY	Oak Leaves Broadcasting Station (Pioneer Pub. Co.)	Oak Park, Ill.	1060	283	500
WTAZ	Thomas J. McGuire	Lambertville, N. J.	1060	283	15
WTG	Kansas State Agri. College	Manhattan, Kans.	1100	273	50
WWAB	Hoenig, Swern & Co.	Trenton, N. J.	1330	225	10
WWAC	Sanger Brothers	Waco, Texas	833	360	50
WWAD	Wright & Wright, Inc.	Philadelphia, Pa.	833	360	500
WWAE	Lawrence J. Crowley	Joliet, Ill	1320	227	500
WWAF	Galvin Radio Supply Co.	Camden, N. J.	1270	236	100
WWAO	Michigan College of Mines	Houghton, Mich.	1230	244	250
WWI	Ford Motor Co.	Dearborn, Mich.	1100	273	250
WWJ	Evening News Ass'n	Detroit, Mich.	580	517	500
WWL	Loyola University	New Orleans, La.	1120	268	100

MEXICAN BROADCASTING STATIONS

CYB	El Buen Tono	S.A. Mex. City, Mex.	681	440	50
CYL	La Casa del Radio	Mexico City, Mex.	600	500	500
8CYR	Rosetter y Cia	Mazatlan, Sinaloa, Mexico	681	440	50

Active Broadcasting Stations, June 15, 1924

CANADIAN BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	The Calgary Herald......	Calgary, Alberta...	697	430	500
CFCA	Star Pub. & Print. Co.....	Toronto, Ontario...	750	400	1000
CFCF	Marconi Wireless Telegrah Co. of Canada.........	Montreal, Quebec..	681	440	500
CFCH	Abitibi Power & Paper Co..	Iroquois Falls, Ont..	750	400	250
CFCJ	La Cie de L'Evenement....	Quebec, Quebec....	731	410	5
CFCK	Radio Supply Co., Ltd....	Edmonton, Alberta.	731	410	50
CFCL	Centennial Me. Church...	Victoria, B. C......	750	400	250
CFCN	W. W. Grant Radio Ltd...	Calgary, Alberta...	681	440	1000
CFCO	Semmelhaack-Dickson, Ltd.	Bellevue, Quebec...	666	450	5
CFCQ	Radio Specialties, Ltd.....	Vancouver, B. C...	666	450	5
CFCR	Laurentide Air Service, Ltd.	Sudbury, Ont......	731	410	50
CFCW	The Radio Shop..........	London, Ont.......	714	420	5
CFDC	Sparks Company.........	Nanaimo, B. C.....	697	430	10
CFQC	The Electric Shop, Ltd....	Saskatoon, Sask....	750	400	100
CFRC	Queens University........	Kingston, Ont......	666	450	500
CFUC	Univ. of Montreal........	Montreal, Quebec..	750	400	500
CFXC	Westminster Trust Co....	NewWestmin'r, B.C.	681	440	20
CHAC	Radio Engineers..........	Halifax, N. S......	750	400	10
CHBC	The Albertan Pub. Co.....	Calgary, Alberta...	731	410	125
CHCB	Marconi Wireless Telegraph Co. of Canada.........	Toronto, Ont......	681	440	1000
CHCD	Canadian Wirel's & Elec. Co.	Quebec, Quebec....	731	410	5
CHCE	Western Can. Radio Supply	Victoria, B. C......	750	400	5
CHCL	The Vancouver Merchants Exchange, Ltd.........	Vancouver, B. C...	681	440	00
CHCM	Riley & McCormack, Ltd..	Calgary, Alberta...	681	440	500
CHCS	The Hamilton Spectator...	Hamilton, Ont.....	731	410	125
CHYC	Northern Elec. Co., Ltd....	Montreal, Quebec...	880	341	500
CJCA	The Edmonton Journal, Ltd.	Edmonton, Alverta.	666	450	125
CJCD	T. Eaton Co., Ltd........	Toronto, Ontario...	731	410	50
CJCE	Sprott-Shaw Radio Co....	Vancouver, B. C...	714	420	50
CJCI	Maritime Radio Corp., Ltd.	St. John, N. B.....	750	400	5
CJCM	J. L. Phillipe Landry......	Monti Joli, Quebec.	750	400	500
CJCN	Simons, Agnew & Co......	Toronto, Ontario...	731	410	1000
CJCX	Percival Wesley Shackleton	Olds, Alberta......	750	400	50
CJGC	London Free Press Printing Co., Ltd..........	London, Ontario....	697	430	50
CJSC	The Evening Telegram....	Toronto, Ontario...	697	430	125
CKAC	La Presse Pub. Co., Ltd....	Montreal, Quebec..	692	425	500
CKCD	Vancouver Daily Province.	Vabcouver, B. C...	731	410	500
CKCE	Canadian Independent Telephone Co..........	Toronto, Ontario...	666	410	1000
CKCH	Canadian National Rys.	Ottawa, Ont.......	690	435	500
CKCK	Leader Pub. Co., Ltd.....	Regina, Sask.......	714	435	500
CKCO	Dr. G. M. Geldert (for Ottawa Radio Assin.)...	Ottawa, Ont........	750	400	50
CKCX	P. Burns & Co., Ltd......	Calgary, Alberta...	681	440	500
CKY	Manitoba Tel. System....	Winnipeg, Manitoba	666	450	500

AUSTRALIAN BROADCASTING STATIONS

2BS	Broadcasters Sydney, Ltd.	Sydney, N. S. W....	857	350	500
2FC	Farmers & Co...........	Sydney, N. S. W....	273	100	5000
2FL	Farmers & Co...........	Sydney, N. S. W....	389	770	500
3AR	Associated Radio Co. of Aust.	Melbourne, Victoria.	625	480	1600
3JO	Broadc'g Co. of Australia	Melbourne, Victoria.	750	400	500
3LO	Broadc'g Co. of Australia	Melbourne, Victoria.	174	1720	5000
3MA	Millswood Auto & Radio Co.	Adelaide, S. Australia	353	480	3000
6AR	Associated Radio Co......	Perth, S. Australia..	833	360	1600
6WF	Westralian Farmers, Ltd...	Perth, W. Australia	240	1250	5000

Active Broadcasting Stations, June 15, 1924

BRITISH BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Raing Oscill. Watts
2BD	17 Belmont St., Aberdeen	Aberdeen Steam Laundry	605	495	1500
6BM	72 Holdenhurst Road, Bournemouth	Bushey Road, North Cemetery	778	385	1500
5IT	105 New Street, Birmingham	Summer Lane Power Station	631	475	1000
2LO	2 Savoy Hill, Victoria Embankment, London, W. C. 2	Marconia House, Strand	821	365	1500
5NO	24 Eldon Sq., Newcastle	CWS Bldg., Blandford Street	750	400	1500
5SC	202 Bath Street, Glasgow	Port Dundas	714	420	1500
5WA	19 Castle Street, Cardiff	Eldon Rd. Generating Station	857	350	1500
2ZY	57 Dickinson St., Manchester	57 Dickinson Street	789	375	1500
6SL	Union Grinding Wheel, Corporation St., Sheffield	Union Grinding Wheel, Corporation Street	[illegible]	303	100

CUBAN BROADCASTING STATIONS

PWX	Cuban Telephone Co.	Havana	750	400	500
2AB	Alberto S. Bustamante	"	1249	240	20
2BY	Frederick W. Borton	"	1153	260	100
2CX	Frederick W. Borton	"	937	320	10
2DW	Pedro Zayas	"	999	300	100
2EV	Westinghouse Electric Co	"	1363	220	50
2HS	Julio Power	"	1666	180	20
2JQ	Raul Perez Falcon	"	1999	150	10
2KD	E. Sanchez de Fuentes	"	857	350	100
2KP	Alvaro Daza	"	1499	200	10
2LC	Luis Casas	"	1199	250	30
2MG	Manuel G. Salas	"	1071	280	20
2OK	Mario Garcia Velez	"	833	360	100
2OL	Oscar Collado	"	1034	290	15
2TW	Roberto E. Ramirez	"	1304	230	20
2WW	Amadeo Saenz	"	1428	210	20
5EV	Leopoldo V. Figueroa	Colon	833	360	100
6AZ	Valenten Ullivarri	Cienfuegos	1499	200	10
6BY	Jose Ganduxe	"	999	300	100
6CX	Antonio T. Figueroa	"	1764	170	20
6DW	Eduardo Terry	"	1330	225	10
6EV	Josefa Alvarez	Caibarien	1330	225	20
6GT	Juan Pablo Ros	Cienfuegos	1578	190	10
6KJ	Frank H. Jones	Tuinicu	1090	275	100
6KW	Frank H. Jones	"	882	340	100
7AZ	Pedro Nogueras	Camaguey	1330	225	10
7BY	Eduardo V. Figueroa	C. De Avila	1275	235	20
7SR	Salvador Rionda	C. Elia	857	350	500
8AZ	Alfredo Broocks	Santiago de Cuba	1249	240	20
8BY	Albeeto Ravelo	" " "	1199	250	100
8DW	Pedro C. Andux	" " "	1666	180	75
8EV	Eduardo Mateos	" " "	1330	225	15
8FU	Andres Vinnet	" " "	1330	225	15
8GT	Juan E. Chibas	" " "	1153	260	50

Broadcasting Stations by Frequency

Kilocycle	Call	Meters	Location
	CLASS B		
550	KSD	545	St. Louis, Mo
560	KYW	535	Chicago, Ill.
570	WHO	526	Des Moines, Ia.
570	WOAW	526	Omaha, Neb.
580	WCX	517	Detroit, Mich.
580	WWJ	517	Detroit, Mich.
590	KLX	508	Oakland, Cal.
590	WIP	508	Philadelphia, Pa.
590	WOO	508	Philadelphia, Pa.
600	WMC	500	Memphis, Tenn.
610	KGW	492	Portland, Ore.
610	WBAY	492	New York, N. Y.
610	WEAF	492	New York, N. Y.
620	WHAA	484	Iowa City, Ia.
620	WOC	484	Davenport, Ia.
630	WBAP	476	Fort Worth, Tex.
630	WFAA	476	Dallas, Tex.
640	KFI	469	Los Angeles, Cal.
640	WCAP	469	Washington, D.C.
640	WRC	469	Washington, D.C.
650	WCAE	461	Pittsburgh, Pa.
660	KFOA	454	Seattle, Wash.
660	WJZ	454	New York, N. Y.
670	WMAQ	448	Chicago, Ill.
670	WQJ	448	Chicago, Ill.
680	WOS	441	Jefferson City, Mo
700	WSB	428	Atlanta, Ga.
710	KPO	422	San Francisco Cal.
720	WBAH	416	Minneapolis, Minn
720	WLAG	416	Minnepaolis, Minn
730	WDAF	411	Kansas City, Mo.
730	WHB	411	Kansas City, Mo.
740	WJY	405	New York, N. Y.
740	WDR	405	Newark, N. J.
750	WBAK	400	Harrisburg, Pa.
750	WHAS	400	Louisville, Ky.
760	KHJ	395	Los Angeles, Cal.
760	WDAR	395	Philadelphia, Pa.
760	WFI	395	Philadelphia, Pa.
770	WBAV	389	Columbus, O.
770	WJAX	389	Cleveland, O.
770	WTAM	389	Cleveland, O.
780	WOAI	384	San Antonio, Tex.
790	WGY	380	Schenectady, N.Y.
790	WHAZ	380	Troy, N. Y.
810	WEBH	370	Chicago, Ill.
	CLASS C		
833	KDYL	360	Salt Lake City, Utah.
833	KDYQ	360	Portland, Ore.
833	KDZI	360	Wenatchee, Wash.
833	KDZQ	360	Denver, Colo.
833	KFAD	360	Phoenix, Ariz.
833	KFAJ	360	Boulder, Colo.
833	KFAN	360	Moscow, Idaho.
833	KFBB	360	Havre, Mont.
833	KFBG	360	Tacoma, Wash.
833	KFBS	360	Trinidad, Colo.
833	KFCF	360	WallaWalla, Wash
833	KFCH	360	Billings, Mont.
833	KFCP	360	Ogden, Utah.
833	KFCV	360	Houston, Tex.
833	KFDA	360	Baker, Ore.
833	KFDJ	360	Corvallis, Ore.
833	KFDR	360	York, Neb.
833	KFDV	360	Fayetteville, Ark.
833	KFDX	360	Shreveport, La.
833	KFDY	360	Brookings, S.Dak.
833	KFEY	360	Kellogg, Idaho.
833	KFFE	360	Pendleton, Ore.
833	KFHJ	360	Santa Barbara, Cal.
833	KFIF	360	Portland, Ore.
833	KGG	360	Portland, Ore.
833	KGN	360	Portland, Ore.
833	KGD	360	Honolulu, Hawaii
833	KHQ	360	Seattle, Wash.
833	KJQ	360	Stockton, Cal.
833	KJS	360	Los Angeles, Cal.
833	KLS	360	Oakland, Cal.
833	KMO	360	Tacoma, Wash.
833	KNX	360	Los Angeles, Cal.
833	KOB	360	State College, N. M.
833	KQP	360	Hood River, Ore.
833	KQW	360	San Jose, Cal.
833	KUO	360	San Francsico, Cal.
833	KTW	360	Seattle, Wash.
833	KWG	360	Stockton, Cal.
833	KWH	360	Los Angeles, Cal.
833	KZM	360	Oakland, Cal.
833	KZV	360	Wenatchee, Wash.
833	WAAC	360	New Orleans, La.
833	WAAD	360	Cincinnati, O.
833	WAAW	360	Omaha, Nebr.
833	WBAA	360	West Lafayette, Ind.
833	WBAO	360	Decatur, Ill.
833	WBAX	360	Wilkes-Barre, Pa.
833	WBS	360	Newark, N. J.
833	WBT	360	Charlotte, N. C.
833	WCAJ	360	Univ. Place, Nebr.
833	WCAL	360	Northfield, Minn.
833	WCAM	360	Villanova, Pa.
833	WCAO	360	Baltimore, Md.
833	WCAR	360	San Antonio, Tex.
833	WCAV	360	Little Rock, Ark.
833	WCAX	360	Burlington, Vt.
833	WCK	360	St. Louis, Mo.
833	WCM	360	Austin, Tex.
833	WDAE	360	Tampa, Fla.
833	WDAO	360	Dallas, Tex.
833	WDAP	360	Chicago, Ill.
833	WDAS	360	Worcester, Mass.
833	WDAU	360	N. Medford, Mass
833	WEAO	360	Columbus, O.
833	WEAP	360	Mobile, Ala.
833	WEAU	360	Sioux City, Ia.
833	WEAY	360	Houston, Tex.
833	WEV	360	Houston, Tex.
833	WFAJ	360	Asheville, N. C.
833	WFAM	360	St. Cloud, Minn.
833	WFAN	360	Hutchinson, Minn
833	WFAQ	360	Cameron, Mo.
833	WGAN	360	Pensacola, Fla.
833	WGAZ	360	South Bend, Ind.
833	WGI	360	Medford Hillside, Mass.
833	WGL	360	Philadelphia, Pa.
833	WHA	360	Madison, Wis.
833	WHAB	360	Galveston, Tex.
833	WHAP	360	Decatur, Ill.

Kilocycle	Call	Meters	Location
833	WHAV	360	Wilmington, Del.
833	WHN	360	New York, N. Y.
833	WIAC	360	Galveston, Tex.
833	WIAU	360	Le Mars, Ia.
833	WIL	360	Washington, D.C.
833	WJAD	360	Waco, Tex.
833	WJAQ	360	Topeka, Kan.
833	WJAR	360	Providence, R. I.
833	WJAT	360	Marshall, Mo.
833	WJX	360	Jersey City, N. J.
833	WKAF	360	Wichita Falls, Tex.
833	WKAP	360	Cranston, R. I.
833	WKAQ	360	San Juan, Porto Rico.
833	WKY	360	Oklahoma City, Okla.
833	WLAJ	360	Waco, Tex.
833	WLAK	360	Bellow Falls, Vt.
833	WLAL	360	Tulsa, Okla.
833	WLAP	360	Louisville, Ky.
833	WLAW	360	New York, N. Y.
833	WLB	360	Minneapolis, Minn
833	WMAB	360	Oklahoma City, Okla.
833	WMAF	360	S. Dartmouth, Mass.
833	WNAD	360	Norman, Okla.
833	WNAQ	360	Charleston, S. C.
833	WNAT	360	Philadelphia, Pa.
833	WNAW	360	Fort Monroe, Va.
833	WNJ	360	Albany, N. Y.
833	WOAD	360	Sigourney, Ia.
833	WOAE	360	Fremont, Nebr.
833	WOAF	360	Tyler, Tex.
833	WOAH	360	Charleston, S. C.
833	WOAN	360	Lawrenceburg, Tenn.
833	WOAO	360	Mishawaka, Ind.
833	WOAT	360	Wilmington, Del.
833	WOI	360	Ames, Ia.
833	WOQ	360	Kansas City, Mo.
833	WPAC	360	Okmulgee, Okla.
833	WPAK	360	Fargo, N. D.
833	WPAM	360	Topeka, Kans.
833	WPAP	360	Winchester, Ky.
833	WPAT	360	El Paso, Tex.
833	WPAU	360	Moorhead, Minn.
833	WQAA	360	Parkesburg, Pa.
833	WQAO	360	New York, N. Y.
833	WQAQ	360	Abilene, Tex.
833	WRAA	360	Houston, Tex.
833	WRAO	360	St. Louis, Mo.
833	WRK	360	Hamilton, O.
833	WRL	360	Schenectady, N. Y.
833	WRM	360	Urbana, Ill.
833	WRR	360	Dallas, Tex.
833	WSAB	360	Cape Girardeau, Mo.
833	WSAC	360	Clemson College, S. C.
833	WSAJ	360	Grove City, Pa.
833	WSAV	360	Houston, Tex.
833	WSY	360	Birmingham, Ala.
833	WWAC	360	Waco, Tex.
833	WWAD	360	Philadelphia, Pa.

CLASS B

Kilocycle	Call	Meters	Location
870	WCBD	345	Zion, Ill.
870	WLS	345	Chicago, Ill.
880	KFKX	341	Hastings, Nebr.
890	WBZ	337	Springfield, Mass.
910	KFAE	330	Pullman, Wash.
920	KDKA	326	E. Pittsburg, Pa.
940	WGR	319	Buffalo, N. Y.
960	KGO	312	Oakland, Cal.
970	WFBW	309	Cincinnati, Ohio.
970	WLW	309	Cincinnati, O.
970	WSAI	309	Cincinnati, O.

CLASS A

Kilocycle	Call	Meters	Location
1050	KFFQ	286	Col. Springs, Col.
1050	KFGZ	286	Berrien Springs, Mich.
1050	KFKB	286	Milford, Kans.
1050	KOP	286	Detroit, Mich.
1050	WAAF	286	Chicago, Ill.
1050	WBR	286	Butler, Pa.
1050	WCAH	286	Columbus, O.
1050	WCAU	286	Philadelphia, Pa.
1050	WEAI	286	Ithaca, N. Y.
1050	WEAM	286	N. Plainfield, N.J.
1050	WKBF	286	Cranston, R. I.
1050	WMAN	286	Columbus, O.
1050	WNAN	286	Syracuse, N. Y.
1050	WPAL	286	Columbus, O.
1050	WTAS	286	Elgin, Ill.
1060	KFAY	283	Medford, Ore.
1060	KFBK	283	Sacramento, Cal.
1060	KFBU	283	Laramie, Wyo.
1060	KFHR	283	Seattle, Wash.
1060	KFKV	283	Butte, Mont.
1060	KFLA	283	Butte, Mont.
1060	KFMX	283	Northfield, Minn.
1060	KFOH	283	Portland, Ore.
1060	KFPY	283	Spokane, Wash.
1060	KJR	283	Seattle, Wash.
1060	KLZ	283	Denver, Colo.
1060	WABD	283	Dayton, O.
1060	WABE	283	Washington, D.C.
1060	WABL	283	Storrs, Conn.
1060	WABO	283	Rochester, N. Y.
1060	WBBL	283	Richmond, Va.
1060	WDBS	283	Dayton, Ohio.
1060	WEAJ	283	Vermillion. S. D.
1060	WHAH	283	Joplin, Mo.
1060	WHAM	283	Rochester, N. Y.
1060	WHK	283	Cleveland, O.
1060	WIAS	283	Burlington, Ia.
1060	WJAG	283	Norfolk, Nebr.
1060	WLAQ	283	Kalamazoo, Mich.
1060	WPAB	283	State College, Pa.
1060	WQAM	283	Miami, Fla.
1060	WTAY	283	Oak Park, Ill.
1060	WTAZ	283	Lambertville, N.J.
1070	KDYM	280	San Diego, Cal.
1070	KFAR	280	Hollywood, Cal.
1070	KFAW	280	Santa Ana, Cal.
1070	KFFV	280	Lamoni, Iowa.
1070	KFHB	280	Hood River, Ore.
1070	KFJM	280	Grand Forks, N.D
1070	KFJQ	280	Grand Forks, N.D
1070	KFJX	280	Cedar Falls, Iowa.
1070	KFQD	280	Anchorage, Alaska
1070	WCAD	280	Canton, N. Y.
1070	WCAS	280	Minneapolis Minn.
1070	WCBA	280	Allentown, Pa.
1070	WCBC	280	Ann Arbor, Mich.
1070	WCBL	280	Houlton, Mo.
1070	WEAA	280	Flint, Mich.
1070	WEAH	280	Wichita, Kans.
1070	WEW	280	St. Louis, Mo.
1070	WHAD	280	Milwaukee, Wis.

Kilocycle	Call	Meters	Location
1070	WJAN	280	Peoria, Ill.
1070	WKAR	280	E. Lansing, Mich.
1070	WKAY	280	Gainesville, Ga.
1070	WMAY	280	St. Louis, Mo.
1070	WQAN	280	Scranton, Pa.
1070	WRAY	280	Scranton, Pa.
1070	WTAR	280	Norfolk, Va.
1070	WTAW	280	College Sta., Tex.
1080	KFAF	278	Denver, Colo.
1080	KFBC	278	San Diego, Cal.
1080	KFFX	278	Omaha, Nebr.
1080	WDBL	278	Stevens Pt., Wis.
1080	WDZ	278	Tuscola, Ill.
1080	WIAK	278	Omaha, Nebr.
1080	WLBL	278	StevensPoint,Wis.
1080	WNAC	278	Boston, Mass.
1080	WRBC	278	Valparaiso, Ind.
1090	KFFY	275	Alexandria, La.
1090	KFMS	275	Duluth, Minn.
1090	KRE	275	Berkeley, Cal.
1090	WABG	275	Jacksonville, Fla.
1090	WBBN	275	Wilmington, Del.
1090	WFAV	275	Lincoln, Nebr.
1090	WMAJ	275	Kansas City, Mo.
1090	WNAP	275	Springfield, O.
1090	WQAE	275	Springfield, Vt.
1090	WSAW	275	Canandaigua, N. Y.
1090	WTAC	275	Johnstown, Pa.
1100	KFGH	273	Stanford Univ., Cal.
1100	KFIZ	273	Fond du Lac, Wis.
1100	KFKA	273	Greeley, Colo.
1100	KFLZ	273	Atlantic, Ia.
1100	WBBR	273	Rossville, N. Y.
1100	WEAN	273	Providence, R. I.
1100	WEB	273	St. Louis, Mo.
1100	WFAF	273	Poughkeepsie,N.Y
1100	WIAY	273	Washington, D.C.
1100	WMAK	273	Lockport, N. Y.
1100	WOAG	273	Belvidere, Ill.
1100	WPAZ	273	Charleston, W.Va.
1100	WRW	273	Tarrytown, N. Y.
1100	WSL	273	Utica, N. Y.
1100	WTG	273	Manhattan, Kans.
1100	WWI	273	Dearborn, Mich.
1110	KDPM	270	Cleveland, O.
1110	KDZE	270	Seattle, Wash.
1110	KFAU	270	Boise, Idaho.
1110	KFJC	270	Seattle, Wash.
1110	KQV	270	Pittsburgh, Pa.
1110	KYQ	270	Honolulu, Hawaii.
1110	WABR	270	Toledo, O.
1110	WABX	270	(Near) Mt. Clemens, Mich.
1110	WBBF	270	Atlanta, Ga.
1120	KFDH	268	Tucson, Ariz.
1120	KFEQ	268	Oak, Neb.
1120	KFLE	268	Denver, Colo.
1120	KFOP	268	Dallas, Tex.
1120	KFPT	268	SaltLakeCity,Utah
1120	KFPW	268	Caterville, Mo.
1120	WAAB	268	New Orleans, La.
1120	WBBY	268	Charleston, S. C.
1120	WCAG	268	New Orleans, La.
1120	WCBG	268	Pascagoula, Miss.
1120	WCBY	268	Buck Hill Falls,Pa
1120	WDAH	268	El Paso, Tex.
1120	WDBD	268	Martinsburg, W. Va.
1120	WDBH	268	Worcester, Mass.
1120	WDBW	268	Columbia, Tenn.
1120	WJAM	268	Cedar Rapids, Ia.
1120	WJAZ	268	Chicago, Ill.
1120	WKAA	268	Cedar Rapids, Ia.
1120	WPAJ	268	New Haven, Conn
1120	WRAX	268	Gloucester City, N. J.
1120	WSAT	268	Plainview, Tex.
1120	WTAF	268	New Orleans, La.
1120	WWL	268	New Orleans, La.
1130	KFFP	266	Moberly, Mo.
1130	KFHF	266	Shreveport, La
1130	KFMW	266	Houghton, Mich.
1130	KFNF	266	Shenandoah, Ia.
1130	WABA	266	Lake Forest, Ill.
1130	WABB	266	Harrisburg, Pa.
1130	WABP	266	Dover, O.
1130	WCAY	266	Milwaukee, Wis.
1130	WCBK	266	St. Petersburg,Fla
1130	WCBN	266	Ft. Benjamin Harrison, Ind.
1130	WNAL	266	Omaha, Nebr.
1130	WOAC	266	Lima, O.
1130	WOK	266	Arkadelphia, Ark.
1130	WQAS	266	Lowell, Mass.
1130	WTAB	266	Fall River, Mass.
1140	KFEV	263	Casper, Wyo.
1140	KFMQ	263	Fayetteville, Ark.
1140	KNT	263	Kukak Bay, Alas.
1140	WAAM	263	Newark, N. J.
1140	WABV	263	Nashville, Tenn.
1140	WABZ	263	New Orleans, La.
1140	WCAK	263	Houston, Tex.
1140	WCBE	263	New Orleans, La.
1140	WDAG	263	Amarillo, Tex.
1140	WSAP	263	New York, N. Y.
1150	KDZR	261	Bellingham, Wash
1150	KFEX	261	Minneapolis,Minn
1150	KFHH	261	Neah Bay, Wash.
1150	KFLH	261	Salt Lake City, Utah.
1150	KFLQ	261	Little Rock, Ark.
1150	KFMR	261	Sioux City, Ia.
1150	KFNY	261	Helena, Mont.
1150	KFOO	261	Salt Lake City, Utah
1150	KFQA	261	St. Louis, Mo.
1150	WABQ	261	Haverford, Pa.
1150	WBL	261	Anthony, Kans.
1150	WDAK	261	Hartford, Conn.
1150	WDBP	261	Superior, Wis.
1150	WEAR	261	Baltimore, Md.
1150	WGAW	261	Altoona, Pa.
1150	WMAC	261	Cazenovia, N. Y.
1150	WMAZ	261	Macon, Ga.
1150	WMU	261	Washington, D.C.
1150	WSAD	261	Providence, R. I.
1160	KFCZ	259	Omaha, Nebr.
1160	KFJR	259	Stevensville, Mont
1160	KGY	259	Lacey, Wash.
1160	WBRJ	259	W. Palm Beach, Fla.
1160	WDBC	259	Lancaster, Pa.
1160	WDBU	259	Skowhegan, Maine
1160	WDBY	259	Fort Wayne, Ind.
1160	WFAT	259	Sioux Falls, S. D.
1160	WOAP	259	Kalamazoo, Mich.
1160	WQAL	259	Mattoon, Ill.
1160	WSAZ	259	Pomeroy, O.

Kilo-cycle	Call	Meters	Location
1160	WTAG	259	Providence, R. I.
1170	KUY	256	Ele Monte, Cal.
1170	WMAL	256	Trenton, N, J.
1170	WDBR	256	Boston. Mass.
1180	KFEL	254	Denver, Colo.
1180	KFGC	254	Baton Rouge, La.
1180	KFJZ	254	Ft. Worth, Tex.
1180	KFLR	254	Albuquerque. N. Mex.
1180	KFMB	254	Little Rock, Ark.
1180	KFNG	254	Coldwater, Miss.
1180	KFOU	254	Richmond, Cal.
1180	KFQB	254	Fort Worth, Tex.
1180	WAAN	254	Columbia, Mo.
1180	WABM	254	Saginaw, Mich.
1180	WCBU	254	Arnold, Pa.
1180	WIAD	254	Philadelphia, Pa.
1180	WJAK	254	Greentown, Ind.
1180	WKAV	254	Laconia, N. H.
1180	WLAV	254	Pensacola, Fla.
1180	WMAH	254	Lincoln, Nebr.
1180	WSAR	254	Fall River, Mass.
1180	WTAQ	254	Osseo, Wis.
1190	KFCY	252	Le Mars, Ia.
1190	KFDD	252	Boise, Idaho.
1190	KFHA	252	Gunnison, Colo.
1190	KFIO	252	Spokane, Wash.
1190	KFJF	252	Oklahoma City, Okla.
1190	KFJI	252	Astoria, Ore.
1190	KFQL	252	Muskogee, Okla.
1190	KGB	252	Tacoma, Wash.
1190	WABT	252	Washington, Pa.
1190	WBBQ	252	Pawtucket, R. I.
1190	WCBV	252	Tullahoma, Tenn.
1190	WDBE	252	Atlanta, Ga.
1190	WDBN	252	Bangor, Me.
1190	WGAQ	252	Shreveport, La.
1190	WIAB	252	Rockford, Ill.
1190	WIAI	252	Springfield, Mo.
1190	WTAL	252	Toledo, O.
1200	KFGX	250	Orange, Tex.
1200	KFKQ	250	Conway, Ark.
1200	KFMZ	250	Roswell, N. M.
1200	WBBO	250	Rodgers, Mich.
1200	WBBS	250	New Orleans, La.
1200	WCBO	250	Memphis, Tenn.
1200	WJAS	250	Pittsburgh, Pa.
1200	WMAV	250	Auburn, Ala.
1210	KFDO	248	Bozeman, Mont.
1210	KFEC	248	Portland, Ore.
1210	KFEZ	248	St. Louis, Mo.
1210	KFGD	248	Chickasha, Okla.
1210	KFJB	248	Marshalltown, Ia.
1210	KFLB	248	Menominee, Mich
1210	KFOX	248	Omaha, Nebr.
1210	KMJ	248	Fresno, Cal.
1210	WBBG	248	Mattapoisett, Mass.
1210	WBBV	248	Johnstown, Pa.
1210	WCBZ	248	Chicago Heights, Ill.
1210	WDBK	248	Cleveland, O.
1210	WGAL	248	Lancaster, Pa.
1210	WQAX	248	Peoria, Ill.
1210	WRAL	248	St. Croix Falls, Wis.
1220	KFID	246	Iola, Kans.
1220	KFJY	246	Ft. Dodge, Ia.
1220	KFOJ	246	Moberly, Mo.

Kilo-cycle	Call	Meters	Location
1220	WBBE	246	Syracuse, N. Y.
1220	WBBH	246	Port Huron, Mich.
1220	WBBP	246	Petoskey, Mich.
1220	WCAZ	246	Carthage, Ill.
1220	WCBR	246	Providence, R. I.
1220	WDBF	246	Youngstown, O.
1220	WIAO	246	Milwaukee, Wis.
1220	WMAP	246	Easton, Pa.
1220	WTAT	246	Boston, Mass.
1230	KDPT	244	San Diego, Cal.
1230	WABN	244	La Crosse, Wis.
1230	WABS	244	Newark, N. J.
1230	WBAN	244	Paterson, N. J.
1230	WCBJ	244	Jennings, La.
1230	WNAX	244	Yankton, S. D.
1230	WRAM	244	Galesburg, Ill.
1230	WSAG	244	St. Petersburg, Fla.
1230	WWAO	244	Houghton, Mich.
1240	KFBE	242	San Luis Obispo, Cal.
1240	KFIQ	242	Yakima, Wash.
1240	KFJL	242	Ottumwa, Ia.
1240	KFPH	242	Salt Lake City, Utah.
1240	KFPL	242	Dublin, Tex.
1240	KFPM	242	Greenville, Tex.
1240	KFPN	242	Jefferson City, Md
1240	KFPS	242	Casper, Wyo.
1240	KFPX	242	Pine Bluff, Ark.
1240	WABY	242	Philadelphia, Pa.
1240	WCBH	242	(Near) Oxford, Miss.
1240	WEBP	242	New Orleans, La.
1240	WGV	242	New Orleans, La.
1240	WOAV	242	Erie, Pa.
1240	WRAV	242	Yellow Sprgs., O.
1240	WTAP	242	Cambridge, Ill.
1240	WTAU	242	Tecumseh, Nebr.
1250	KDZB	240	Bakersfield, Cal.
1250	KFFB	240	Boise, Idaho.
1250	KFIX	240	Independence, Mo
1250	KFLP	240	Cedar Rapids, Ia.
1250	KFLX	240	Galveston, Tex.
1250	KFMU	240	San Marcos, Tex.
1250	KFNL	240	Paso Robles, Cal.
1250	KFNX	240	Peabody, Kans.
1250	KFOF	240	Marshfield, Ore.
1250	KFOQ	240	Galveston, Tex.
1250	WABH	240	Sandusky, O.
1250	WABI	240	Bangor, Me.
1250	WBBA	240	Newark, O.
1250	WCAT	240	Rapid City, S.Dak
1250	WCBI	240	Bemis, Tenn.
1250	WDBO	240	Winter Park, Fla.
1250	WKAD	240	East Providence, R. I.
1250	WOAX	240	Trenton, N. J.
1250	WQAF	240	Sandusky, O.
1260	KFCB	238	Phoenix, Ariz.
1260	KFPG	238	Los Angeles, Cal.
1260	WBBD	238	Reading, Pa.
1260	WCBT	238	Worcester, Mass.
1260	WHAK	238	Clarksburg, W. Va.
1260	WRAW	238	Reading, Pa.
1270	KFLU	236	San Benito, Tex.
1270	KFNH	236	Springfield, Mo.
1270	KFOC	236	Whittier, Cal.
1270	KFPP	236	Olympia, Wash.
1270	KFPV	236	SanFrancisco, Cal.

Kilocycle	Call	Meters	Location
1270	KFQJ	236	Oklahoma City, Okla.
1270	KFQK	236	Fayette, Mo.
1270	WCBF	236	Pittsburgh, Pa.
1270	WCBQ	236	Nashville, Tenn.
1270	WDBA	236	Columbus, Ga.
1270	WDBT	236	Hattlesburg,Miss.
1270	WFAH	236	Port Arthur, Tex.
1270	WNAV	236	Knoxville, Tenn.
1270	WPAR	236	Beloit, Kans.
1270	WQAW	236	Washington, D.C.
1270	WRAN	236	Waterloo, Ia.
1270	WTAH	236	Belvidere, Ill.
1270	WTAJ	236	Portland, Me.
1270	WWAF	236	Camden, N. J.
1280	KFGL	234	Arlington, Ore.
1280	KFIL	234	Louisburg, Kans.
1280	KFJK	234	Bristow, Okla.
1280	KFKZ	234	Colorado Springs, Colo.
1280	KFLD	234	Franklinton, La.
1280	KFLW	234	Missoula, Mont.
1280	KFNC	234	Corsicana, Tex.
1280	KFNJ	234	Warrensburg, Mo.
1280	KFNV	234	Santa Rosa, Cal.
1280	KFOL	234	Marengo, Ia.
1280	KFON	234	Long Beach, Cal.
1280	KFOY	234	Sioux City, Ia.
1280	KFQI	234	Culver City, Cal.
1280	KFSG	234	Los Angeles, Cal.
1280	WABW	234	Wooster, O.
1280	WBBT	234	Philadelphia, Pa.
1280	WDBQ	234	Salem, N. J.
1280	WDM	234	Washington, D.C.
1280	WFAB	234	Syracuse, N. Y.
1280	WIAF	234	New Orleans, La.
1280	WIK	234	McKeesport, Pa.
1280	WLAH	234	Syracuse, N. Y.
1280	WQAC	234	Amarillo, Tex.
1290	KFOZ	232	Ft. Smith, Ark.
1290	WCBX	232	Newark, N. J.
1290	WSAY	232	Pt. Chester, N.Y.
1300	KFDZ	231	Minneapolis,Minn
1300	KFER	231	Fort Dodge, Ia.
1300	KFLY	231	Fargo, N. D.
1300	KFMT	231	Minneapolis,Minn
1300	KFNZ	231	Burlingame, Cal.
1300	KFOT	231	Wichita, Kans.
1300	KFPO	231	Denver, Colo.
1300	KFPQ	231	Denison, Tex.
1300	KFPR	231	Los Angeles, Cal.
1300	KFQH	231	Hillsbourgh, Cal.
1300	WHAR	231	Atlantic City,N.J.
1300	WLAX	231	Greencastle, Ind.
1300	WNAR	231	Butler, Mo.
1300	WRAH	231	Providence, R. I.
1300	WTAX	231	Streator, Ill.
1310	KFFO	229	Hillsboro, Ore.
1310	KFHX	229	Hutchinson, Kans
1310	KFLV	229	Rockford, Ill.
1310	KFMY	229	Long Beach, Cal.
1310	WCBM	229	Baltimore, Md.
1310	WDBB	229	Taunton, Mass.
1310	WDBJ	229	Roanoke, Va.
1310	WJAB	229	Lincoln, Neb.
1310	WJD	229	Granville, O.
1310	WOAR	229	Kenosha, Wis.
1310	WSAN	229	Allentown, Pa.
1310	WSAU	229	Chesham, N. H.
1320	KFQC	227	Taft, Cal.
1320	WBBZ	227	Indianapolis, Ind.
1320	WCBW	227	Macon, Ga.
1320	WWAE	227	Joilet, Ill.
1330	KFLR	225	Sparks, Nev.
1330	KFFZ	225	Dallas, Tex.
1330	KFGQ	225	Boone, Ia.
1330	KFHD	225	St. Joseph, Mo.
1330	KFIU	225	Juneau, Alas.
1330	KFOR	225	David City, Nebr.
1330	KFOY	225	St. Paul, Minn.
1330	KFQG	225	Los Angeles, Cal.
1330	WABU	225	Camden, N. J.
1330	WBBM	225	Lincoln, Ill.
1330	WCBW	225	Macon, Ga.
1330	WDBI	225	St.Petersburg,Fla.
1330	WIAQ	225	Marion, Ind.
1330	WKAN	225	Montgomery, Ala.
1330	WWAB	225	Trenton, N. J.
1340	KFBL	224	Everett, Wash.
1340	KFGV	224	Utica, Nebr.
1340	KFJV	224	Dexter, Ia.
1340	KFOD	224	Wallace, Idaho.
1340	KFPB	224	Seattle, Wash.
1340	KFQE	224	Colorado Springs, Colo.
1340	KFQF	224	Minneapolis, Minn.
1340	WBBU	224	Monmouth, Ill.
1340	WIAJ	224	Neenah, Wis.
1340	WRAF	224	Laparte, Ind.
1350	WBBW	222	Norfolk, Va.
1350	WHAG	222	Cincinnati, O.

TABLE OF CONDENSER CAPACITIES

The following table gives the values of the various condensers measured by us. In the case of vernier condensers two sets of values are given, one set for the vernier in, and the other for the vernier out. The scale, as indicated at the top of the list, has 100 divisions to the semi-circumference. The values given are very accurate for the particular instruments which we measured, but the reader must understand that any slight knock or bump may change the capacity of the condenser, as also any slight difference in assembly or manufacture which can be overcome in production methods. The small differences encountered by reason of these things, however are not very great, and will make no difference to the ordinary user. The table gives the capacities in micro-microfarads which may be changed to microfarads by moving the decimal point 6 places to the left, thus, 1060 $\mu\mu f$ = .001060 μf; 160$\mu\mu f$ =.000160 μf; 16 $\mu\mu f$ = .000016 μf.

GEOGRAPHICAL LIST OF BROADCASTING STATIONS

June 15, 1924

(See Alphabetical List for details)

Alabama	
Auburn	WMAV
Birmingham	WSY
Mobile	WEAP
Montgomery	WKAN
Alaska	
Anchorage	KFQD
Juneau	KFIU
Kukak Bay	KNT
Arizona	
Phoenix	KFAD
	KFCB
Tucson	KFDH
Arkansas	
Arkadelphia	WOK
Conway	KFKQ
Fayetteville	KFDV
	KFMQ
Fort Smith	KFOZ
Little Rock	KFLQ
	KFMB
	WCAV
Pine Bluff	KFPX
California	
Bakersfield	KDZB
Berkeley	KRE
Burlingame	KFNZ
Culver City	KFQI
El Monte	KUY
Fresno	KMJ
Hillsbourgh	KFQH
Hollywood	KFAR
Long Beach	KFMY
	KFON
Los Angeles	KFI
	KFPG
	KFPR
	KFQG
	KFSG
	KHJ
	KJS
	KNX
	KWH
Oakland	KGO
	KLS
	KLX
	KZM
Paso Robles	KFNL
Richmond	KFOU
Sacramento	KFBK
San Diego	KDPT
	KDYM
	KFBC
San Francisco	KFPV
	KPO
	KUO
San Jose	KQW
San LuisObispo	KFBE
Santa Ana	KFAW
Santa Barbara	KFHJ
Santa Rosa	KFNV
Stanford Univ.	KFGH
Stockton	KJQ
	KWG
Taft	KFQC
Whittier	KFOC
Colorado	
Boulder	KFAJ
Colorado Sprgs	KFFQ
	KFKZ
	KFQE
Denver	KDZQ
	KFAF
	KFEL
	KFLE
	KFPO
	KLZ
Greeley	KFKA
Gunnison	KFHA
Trinidad	KFBS
Connecticut	
Hartford	WDAK
New Haven	WPAJ
Storrs	WABL
Delaware	
Wilmington	WHAV
	WOAT
District of Columbia	
Washington	WABE
	WCAP
	WDM
	WIAY
	WIL
	WMU
	WQAW
	WRC
Florida	
Jacksonville	WABG
Miami	WQAM
Pensacola	WGAN
	WLAV
St. Petersburg	WCBK
	WDBI
	WSAG
Tampa	WDAE
W. Palm Beach	WBBJ
Winter Park	WDBO
Georgia	
Atlanta	WBBF
	WDBE
	WSB
Colombus	WDBA
Gainesville	WKAY
Macon	WCBW
	WMAZ
Hawaii	
Honolulu	KGU
	KYQ
Idaho	
Boise	KFAU
	KFDD
	KFFB
Kellogg	KFEY
Moscow	KFAN
Wallace	KFOD
Illinois	
Belvidere	WOAG
	WTAH
Cambridge	WTAP
Carthage	WCAZ
Chicago	KYW
	WAAF
	WDAP
	WEBH
	WJAZ
	WLS
	WMAQ
	WQJ
Chicago Heights	WCBZ
Decatur	WBAO
Decatur	WHAP
Elgin	WTAS
Galesburg	WRAM
Joliet	WWAE
Lake Forest	WABA
Lincoln	WBBM
Mattoon	WQAL
Monmouth	WBBU
Oak Park	WTAY
Peoria	WJAN
	WQAX
Rockford	KFLV
	WIAB
Streator	WTAX
Tuscola	WDZ
Urbana	WRM
Zion	WCBD
Indiana	
Ft. Benjamin Harrison	WCBN
Ft. Wayne	WDBV
Greencastle	WLAX
Greentown	WJAK
Indianapolis	WBBZ
Laporte	WRAF
Marion	WIAQ
Mishawaka	WOAO
South Bend	WGAZ
Valparaiso	WRBC
West Lafayette	WBAA
Iowa	
Ames	WOI
Atlantic	KFLZ
Boone	KFGQ
Burlington	WIAS
Cedar Falls	KFJX
Cedar Rapids	KFLP
	WJAM
	WKAA
Davenport	WOC
Des Moines	WHO
Dexter	KFJV
Fort Dodge	KFER
	KFJY
Iowa City	WHAA
Lamoni	KFFV
Le Mars	KFCY
	WIAU
Marengo	KFOL
Marshalltown	KFJB
Ottumwa	KFJL

Geographical List of Broadcasting Stations, June 15, 1924
(See Alphabetical List for details)

Shenandoah....	KFNF
Sigourney......	WOAD
Sioux City.....	KFMR
	KFOV
	WEAU
Waterloo......	WRAN
Kansas	
Anthony.......	WBL
Beloit.........	WPAR
Hutchinson....	KFHX
Iola...........	KFID
Louisburg......	KFIL
Manhattan....	WTG
Milford........	KFKB
Peabody.......	KFNX
Topeka........	WJAQ
	WPAM
Wichita.......	KFOT
	WEAH
Kentucky	
Louisville......	WHAS
	WLAP
Winchester....	WPAP
Louisiana	
Alexandria.....	KFFY
Baton Rouge...	KFGC
Franklinton....	KFLD
Jennings.......	WCBJ
New Orleans...	WAAB
	WAAC
	WABZ
	WBBS
	WCAG
	WCBE
	WEBP
	WGV
	WIAF
	WTAF
	WWL
Shreveport.....	KFDX
	KFHF
	WGAQ
Maine	
Bangor........	WABI
	WDBN
Houlton.......	WCBL
Portland.......	WTAJ
Skowhegan....	WDBU
Maryland	
Baltimore......	WCAO
	WCBM
	WEAR
Massachusetts	
Boston........	WDBR
	WNAC
	WTAT
Fall River.....	WSAR
	WTAB
Lowell........	WQAS
Mattapoisett...	WBBG
Medford Hillside	WGI
New Bedford...	WDAU
S. Dartmouth..	WMAF
Springfield.....	WBZ
Taunton.......	WDBB
Worcester.....	WCBT
	WDAS

Worcester.....	WDBH
Michigan	
Ann Arbor.....	WCBC
Berrien Springs.	KFGZ
Dearborn......	WWI
Detroit........	KOP
	WCX
	WWJ
East Lansing...	WKAR
Flint..........	WEAA
Houghton.....	KFMW
	WWAO
Kalamazoo....	WLAQ
	WOAP
Menominee....	KFLB
Mt. Clemens...	WABX
Petoskey......	WBBP
Port Huron....	WBBH
Rodgers.......	WBBO
Saginaw.......	WABM
Minnesota	
Duluth........	KFMS
Hutchinson....	WFAN
Minneapolis....	KFDZ
	KFEX
	KFMT
	KFQF
	WBAH
	WCAS
	WLAG
	WLB
Moorhead.....	WPAU
Northfield.....	KFMX
	WCAL
St. Cloud......	WFAM
St. Paul.......	KFOY
Mississippi	
Coldwater.....	KFNG
Hattiesburg....	WDBT
Oxford........	WCBH
Pascagoula.....	WCBG
Missouri	
Butler.........	WNAR
Cameron......	WFAQ
Cape Girardeau	WSAB
Columbia......	WAAN
Fayette.......	KFQK
Independence..	KFIX
Jefferson City..	KFPN
	WOS
Joplin.........	WHAH
Kansas City...	WDAF
	WHB
	WMAJ
	WOQ
Marshall.......	WJAT
Moberly.......	KFFP
	KFOJ
St. Joseph.....	KFHD
St. Louis......	KFEZ
	KFQA
	KSD
	WCK
	WEB
	WEW
	WMAY

St. Louis.....	WRAO
Springfield.....	KFNH
	WIAI
Warrensburg...	KFNJ
Montana	
Billings........	KFCH
Bozeman......	KFDO
Butte.........	KFKV
	KFLA
Havre.........	KFBB
Helena........	KFNY
Missoula......	KFLW
Stevensville....	KFJR
Nebraska	
David City....	KFOR
Fremont.......	WOAE
Hastings.......	KFKX
Lincoln........	WFAV
	WJAB
	WMAH
Norfolk.......	WJAG
Oak...........	KFEQ
Omaha........	KFCZ
	KFFX
	KFOX
	WAAW
	WIAK
	WNAL
	WOAW
Tecumseh......	WTAU
Univ. Place....	WCAJ
Utica..........	KFGV
York..........	KFDR
Nevada	
Sparks........	KFFR
New Hampshire	
Chesham......	WSAU
Laconia.......	WKAV
New Jersey	
Atlantic City...	WHAR
Camden.......	WABU
	WWAF
Gloucester City.	WRAX
Jersey City....	WJX
Lambertville...	WTAZ
Newark.......	WAAM
	WABS
	WBS
	WCBX
	WOR
North Plainfield	WEAM
Paterson.......	WBAN
Salem.........	WDBQ
Trenton.......	WMAL
	WOAX
	WWAB
New Mexico	
Albuquerque...	KFLR
Roswell.......	KFMZ
State College...	KOB
New York	
Albany........	WNJ
Buffalo........	WGR
Canandaigua...	WSAW
Canton........	WCAD

Geographical List of Broadcasting Stations, June 15, 1924
(See Alphabetical List for details)

Cazenovia	WMAC
Ithaca	WEAI
Lockport	WMAK
New York City	WBAY
	WEAF
	WHN
	WJY
	WJZ
	WLAW
	WQAO
	WSAP
Port Chester	WSAY
Poughkeepsie	WFAF
Rochester	WABO
	WHAM
Rossville	WBBR
Schenectady	WGY
	WRL
Syracuse	WBBE
	WFAB
	WLAH
	WNAN
Tarrytown	WRW
Troy	WHAZ
Utica	WSL
North Carolina	
Asheville	WFAJ
Charlotte	WBT
Wilmington	WBBN
North Dakota	
Fargo	KFLY
	WDAY
	WPAK
Grand Forks	KFJM
	KFJQ
Ohio	
Cincinnati	WAAD
	WFBW
	WHAG
	WLW
	WSAI
Cleveland	KDPM
	WDBK
	WHK
	WJAX
	WTAM
Columbus	WBAV
	WCAH
	WEAO
	WMAN
	WPAL
Dayton	WABD
	WDBS
Dover	WABP
Granville	WJD
Hamilton	WRK
Lima	WOAC
Newark	WBBA
Pomeroy	WSAZ
Sandusky	WABH
	WQAF
Springfield	WNAP
Toledo	WABR
	WTAL
Wooster	WABW
Yellow Springs	WRAV
Youngstown	WDBF

Oklahoma	
Bristow	KFJK
Chickasha	KFGD
Muskogee	KFQL
Norman	WNAD
Oklahoma City	KFJF
	KFQJ
	WKY
	WMAB
Okmulgee	WPAC
Tulsa	WLAL
Oregon	
Arlington	KFGL
Astoria	KFJI
Baker	KFDA
Corvallis	KFDJ
Hillsboro	KFFO
Hood River	KFHB
	KQP
Marshfield	KFOF
Medford	KFAY
Pendleton	KFFE
Portland	KDYQ
	KFEC
	KFIF
	KFOH
	KGG
	KGN
	KGW
Pennsylvania	
Allentown	WCBA
	WSAN
Altoona	WGAW
Arnold	WCBU
Buck Hill Falls	WCBY
Butler	WBR
Easton	WMAP
East Pittsburgh	KDKA
Erie	WOAV
Grove City	WSAJ
Harrisburg	WABB
	WBAK
Haverford	WABQ
Johnstown	WBBV
	WTAC
Lancaster	WDBC
	WGAL
McKeesport	WIK
Parkesburg	WQAA
Philadelphia	WABY
	WBBT
	WCAU
	WDAR
	WFI
	WGL
	WIAD
	WIP
	WNAT
	WOO
	WWAD
Pittsburgh	KQV
	WCAE
	WCBF
	WJAS
Reading	WBBD
	WRAW
Scranton	WQAN

Scranton	WRAY
State College	WPAB
Villanova	WCAM
Washington	WABT
Wilkes-Barre	WBAX
Porto Rico	
San Juan	WKAQ
Rhode Island	
Cranston	WKAP
	WKBF
Pawtucket	WBBQ
Providence	WCBR
	WEAN
	WJAR
	WKAD
	WRAH
	WSAD
	WTAG
South Carolina	
Charleston	WBBY
	WNAQ
	WOAH
Clemson College	WSAC
South Dakota	
Brookings	KFDY
Rapid City	WCAT
Sioux Falls	WFAT
Vermillion	WEAJ
Yankton	WNAX
Tennessee	
Bemis	WCBI
Columbia	WDBW
Knoxville	WNAV
Lawrenceburg	WOAN
Memphis	WCBO
	WMC
Nashville	WABV
	WCBQ
Tullahoma	WCBV
Texas	
Abilene	WQAQ
Amarillo	WDAG
Austin	WCBO
	WCM
College Station	WTAW
Corsicana	KFNC
Dallas	KFFZ
	KFOP
	WDAO
	WFAA
	WRR
Denison	KFPQ
Dublin	KFPL
El Paso	WDAH
	WPAT
Fort Worth	KFJZ
	KFQB
	WBAP
Galveston	KFLX
	KFOQ
	WHAB
	WIAC
Greenville	KFPM
Houston	KFCV
	WCAK
	WEAY

Geographical List of Broadcasting Stations, June 15, 1924
(See Alphabetical List for details)

Houston.......WEV
WRAA
WSAV
Orange.........KFGX
Plainview......WSAT
Port Arthur....WFAH
San Antonia....WCAR
WOAI
San Benito.....KFLU
San Marcos....KFMU
Tyler..........WOAF
Waco..........WJAD
WLAJ
WWAC
Wichita Falls...WKAF

Utah

Ogden.........KFCP
Salt Lake City.KDYL
KFLH
KFOO
KFPH
KFPT

Vermont

Bellows Falls...WLAK
Burlington.....WCAX
Springfield.....WQAE

Virginia

Fort Monroe...WNAW
Norfolk.......WBBW
WTAR
Richmond.....WBBL
Roanoke.......WDBJ

Washington

Bellingham....KDZR
Everett........KFBL
Lacey..........KGY
Neah Bay.....KFHH
Olympia.......KFPP
Pullman.......KFAE
Seattle........KDZE
KFHR
KFJC
KFOA
KFPB
KHQ
KJR
KTW
Spokane.......KFIO
KFPY
Tacoma.......KFBG
KGB
KMO
Walla Walla...KFCF
Wenatchee.....KDZI
KZV
Yakima........KFIQ

West Virginia

Charleston.....WPAZ
Clarksburg.....WHAK
Martinsburg...WDBD

Wisconsin

Fond du Lac...KFIZ
Kenosha.......WOAR
La Crosse......WABN
Madison.......WHA
Milwaukee.....WCAY
WHAD
WIAO
Neenah........WIAJ
Osseo..........WTAQ
St. Croix Falls..WRAL
Stevens Point..WDBL
WLBL
Superior.......WDBP

Wyoming

Casper.........KFEV
KFPS
Laramie.......KFBU

CANADIAN STATIONS

Alberta

Calgary.......CFAC
CFCN
CHBC
CHCM
CKCX
Edmonton.....CFCK
CJCA
Olds..........CJCX

British Columbia

Nanaimo......CFDC
N.Westminster.CFXC
Vancouver.....CFCQ
CHCL
CJCE
CKCD
Victoria.......CFCL
CHCE

Manitoba

Winnipeg......CKY

New Brunswick

St. John.......CJCI

Nova Scotia

Halifax........CHAC

Ontario

Hamilton......CHCS
Iroquois Falls..CFCH
Kingston......CFRC
London........CFCW
CJGC
Ottawa........CKCH
CKCO
Sudbury.......CFCR
Toronto.......CFCA
CHCB
CJCD
CJCN
CJSC
CKCE

Quebec

Bellevue.......CFCO
Monti Joli.....CJCM
Montreal......CFCF
CFUC
CHYC
CKAC
Quebec........CFCJ
CHCD

Saskatchewan

Saskatoon.....CFQC
Regina........CKCK

The Rest of the Story

We have been continually receiving letters from our readers asking for information on the complete Lefax line. To meet this desire in an efficient manner we have prepared a combination catalog and price list which tells the whole story in a very interesting style.

We will be glad to send a copy to all who indicate their interest by letter or card.

DEFINITIONS OF RADIO TERMS

Absorption Modulation: The process of varying the amplitude of a radio-frequency alternating current in accordance with any desired wave form by systematically absorbing energy from the alternating current circuit in an element of a circuit which serves as an appropriately variable resistance. For example: Using the plate circuit of a three-electrode tube as a variable resistance and varying such resistance by means of suitable voltages impressed on the grid; or, by coupling such a variable resistance to the antenna circuit of a radio transmitting set.

Admittance: The inverse of inductive reactance, i. e., 1 ÷ (6.28 × frequency × inductance).

Air Condenser: A condenser having air as its dielectric, together with a minimum of solid dielectric used as mechanical support.

Alternating Current: Current which periodically reverses its direction of flow in a circuit.

Alternating-Current Characteristic: The relation given by the curve obtained when the impressed emf. is plotted as abscissas against the resultant current as ordinates for alternating emf. and current.

Alternation: One-half a complete cycle; that part of a cycle during which the current flow is in one direction. See cycle.

Ampere: The unit of current. One ampere flows in a d-c circuit whose resistance is one ohm, when an electromotive force of one volt is present in the circuit.

Ampere-hour: The product of the current in a circuit and the number of hours it flows. A unit of work or electrical energy.

Amplification Factor: The ratio of the change of instantaneous voltage between filament and plate to a small change of instantaneous voltage between filament and grid for a given constant plate current.

Amplifier: A device which modifies the effect of a local source of power in accordance with the variations of input power, and produces an increased output power.

Amplitude: The maximum ordinate of an alternating current or voltage characteristic; the maximum value the current or voltage attains during a cycle.

Antenna: A device for radiating or absorbing radio waves.

Antenna, Coil: See Coil Antenna.

Antenna Resistance: An effective resistance which is numerically equal to the ratio of the average power dissipated in the entire antenna circuit to the square of the effective current at the point of maximum current.

Note.—Antenna Resistance includes: Radiation Resistance; Ground Resistance; Radio-frequency resistance of conductors in antenna circuit and equivalent re-

sistance of conductors in the antenna circuit; equivalent resistance due to corona, eddy currents, insulator leakage, dielectric loss, and so on. (See Effective Height of Antenna.)

Anti-Resonance: See Parallel Resonance.

Aperiodic Circuit: An electric circuit in which a voltage impulse will produce transient current in one direction only. The word aperiodic means "without period." Free oscillations are not possible in an aperiodic circuit.

Arc Transmission: The transmission of radio messages by continous waves produced by an electric arc.

Atmospherics: See Strays.

Atmospheric Absorption: Diminishing of the amplitude of electromagnetic radiation due to absorption of energy by the atmosphere.

Attenuation: (Radio)—The decrease, with distance from the radiation source, of the amplitude of the electric and magnetic components constituting an electromagnetic wave.

Audibility: (Radio Telegraph)—A measure of the ratio of the telephone current producing a signal in a telephone receiver to that producing a barely audible signal. (A barely audible signal is one which permits the differentiation of the dot and dash elements of the letters.)

Audio Frequencies: The frequencies corresponding to normally audible sound waves. These lie below about 10,000 cycles per second.

Autodyne Reception: See Self-Heterodyne Reception.

Band of Wave Lengths: A continuous range of wave lengths extending between two definite wave lengths.

Beat Frequency: When two currents of slightly different frequencies flow simultaneously in a circuit, the beat frequency is the difference between the two separate frequencies.

Buzzer Modulation: The process of varying the output power of a continuous-wave generator at the tonal frequency of a buzzer, either by: (a) using the buzzer as a chopper or audio-frequency interrupter in the output circuit of the generator, or a circuit suitably coupled thereto, or (b) using the buzzer element in a circuit of the continuous-wave generator which permits the ready control of the output power of the generator (e.g., the grid circuit of a three-electrode tube oscillator).

By-Pass Condenser: A condenser used to provide a path for alternating current around some circuit element through which current of high frequency cannot readily pass.

Capacitive Coupling: The association of one circuit with another by means of capacity common or mutual to both.

Capacitive Reactance: That part of the impedance which is due to the presence of capacity in the circuit and which is equal to $-1 \div (6.28 \times \text{frequency} \times \text{capacity})$.

Capacity: The ratio of the quantity of electric charge in a condenser to the voltage across its terminals.

Cat-whisker: The fine wire making contact with a crystal detector.

Choke coil: A coil possessing great inductive reactance; used for preventing the flow of high frequency currents into or out of oscillating circuits.

Chopper: A device used in transmitting circuits for modulating continuous wave signals; also known as a "tikker."

Coil Antenna: An antenna consisting of one or more complete turns of wire.

Condenser: A device having capacity, consisting of insulating material (which may be air) between two conducting plates or sets of plates.

Condenser Antenna: An antenna consisting of two capacity areas. The lower capacity area may be ground or counterpoise.

Conductance: The inverse of resistance, i. e., 1 ÷ resistance.

Continuous Waves: Continuous waves (C W) are a succession of waves of constant amplitude and frequency.

Continuous Waves, Interrupted (I C W): See Interrupted Waves.

Continuous Waves, Key Modulated: Continuous waves of which the amplitude or frequency is varied by the operation of a transmitting key.

Continuous Waves, Modulated at Audio Frequency: Continuous waves of which the amplitude or frequency is varied in a periodic manner at an audible frequency.

Counterpoise: A system of wires or other conductors (not the ground) forming the lower plate of a condenser antenna.

Coupler: An apparatus which is used to transfer radio-frequency power from one circuit to another by associating together portions of these circuits. Couplers are of the same types as the types of coupling—inductive, capacitive, and resistive.

Coupling Coefficient: The ratio of the mutual or common impedance component of two circuits to the square root of the product of the total impedance components of the same kind in the two circuits. (Impedance components are either resistance, capacity, or reactance.)

Coupling, Capacitive: See Capacitive Coupling.

Current: The rate of flow of electricity in a circuit.

C. W.: Abbreviation for "continuous wave."

Cycle: A complete succession of events, during which the voltage or current in a circuit passes through all possible values. A complete set of positive and negative values of an alternating current.

Damped Alternating Current: A current passing through successive cycles of value with progressively diminishing amplitude, the average value being zero.

Decrement: The diminishing of the amplitude of successive free oscillations in an oscillatory circuit.

Decremeter: An instrument for measuring the logarithmic decrement of a circuit or of a train of logarithmically damped radio waves.

Detector: That portion of the receiving apparatus which, connected to a circuit carrying currents of radio frequency, and in conjunction with a self-contained or separate indicator, translates the radio-frequency power into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio-frequency power or by means of the control of local power. The indicator may be a telephone receiver, relaying device, tape recorder, and so on.

Dielectric: That portion of a condenser between the plates; it may be air or any non-conducting material.

Diode: A two element vacuum tube, often used as a detector or rectifier; similar to the "Fleming Valve."

Direct Coupling: Association of two radio circuits by having an inductor, a condenser, or a resistor, common to both circuits.

Direct Current: Current which flows always in the same direction in a circuit; unidirectional.

Direct-Current Characteristic: The relation given by the curve plotted between the impressed electromotive force as abscissas and the resultant current as ordinates, for direct emf. and current.

Direction Finder: A radio receiving system which permits determination of the direction of the line of travel of received radio waves.

Directive Antenna: One having the property of radiating radio waves in larger proportion along some directions than others.

Double Modulation: The process of modulating a radio-frequency alternating current successively at two lower frequencies. The intermediate frequency is usually above the range of audio frequencies. The lowest frequency is generally an audio frequency or combination of audio frequencies, as in radio telephony.

Down Lead: That portion of a transmitting or receiving antenna which serves to connect the larger portion of an antenna or the main elevated conductor to the transmitting or receiving set, or through tuning inductors or condensers to the ground connection or counterpoise system.

Duplex Signaling: The simultaneous transmission and reception of signals in both directions between two stations.

Dynatron: A three-electrode tube which depends for its action upon the liberation of electrons from an anode by electron bombardment.

Effective e. m. f.: In a-c circuits, when the wave form of the voltage is sinusoidal, $=0.707 \times$ maximum voltage occuring during the cycle.

Effective Height of an Antenna: The effective height of an antenna is a height somewhat less than the measured height, upon which the absorbing and radiating qualities of an antenna depend. This lessening of the apparent height is due to the presence of surrounding objects.

Electrolyte: The active liquid in a battery or electrolytic rectifier.

Electromotive Force (emf.) Electric pressure; that force which tends to cause a current to flow. The unit of electromotive force is the volt, often referred to as the "difference of potential" between two points in the circuit.

Electron: The smallest component of matter which has been discovered. Regarded as the ultimate particle of matter, carrying a negative electric charge.

Electron Tube, See Three-Electrode Tube.

Electron Tube Rectifier: A device for rectifying an alternating current by utilizing electron flow between a hot cathode and a relatively cold anode in a vacuum.

Electrostatic Coupling: See Capacitive Coupling.

Ether: A fictitious agency existing in space by means of which electromagnetic waves are propagated.

The existance of the ether has been assumed for the purpose of aiding in the explanation of radiation phenomena.

Fading: A variation or diminution of the strength of received radio signals over prolonged, temporary or varying periods, caused by actual variation of wave intensity.

Farad: The unit of capacity. A condenser which holds one coulomb of electricity having a difference of potential of one volt between its terminals has a capacity of one farad. The microfarad, which is one-millionth of the farad is the unit generally used in radio calculations.

Feed-Back Coil: A coil designed to cause mutual action between the input and output circuits of an amplifying device, thereby increasing the amplification.

Feed-Back or Reaction Coupling (sometimes termed "Tickler" Coupling): The process by which a part of the output power of an amplifying device reacts upon the input circuit, thereby increasing the amplification.

Feed-Voltage Modulation: The process of varying the amplitude of a radio-frequency alternating current in accordance with any desired wave form by systematically introducing additional power into the circuit of the radio-frequency generator in accordance with the desired wave-form variations. In the three-electrode tube this involves systematically varying the supply voltage of the plate circuit.

Filter, Band Pass: A combination of electric circuits which present low attenuation to alternating currents of all frequencies between certain limiting border frequencies and comparatively high attenuation to alternating currents of all frequencies below the low limiting border frequency or above the upper limiting border frequency.

Filter, High Pass: A combination of electric circuits which present high attenuation to alternating currents below a certain frequency and comparatively low attenuation to currents above that frequency.

Filter, Low Pass: A combination of electric circuits which present high attenuation to alternating currents above a certain frequency and comparatively low attenuation to currents below that frequency.

Flat-Top Antenna: An antenna having horizontal conductors at the top.

Forced Alternating Current: A current having a frequency and wave form which are equal to the frequency and wave form of the impressed electromotive force.

Free Alternating Current: A damped alternating current following a transient electromagnetic disturbance in a circuit, with no external emf. acting.

Frequency: The number of complete cycles or half the number of reversals per second of direction of current flow of a wave, or in a circuit. The units in use are the cycle and the kilocycle (one thousand cycles).

Frequency Changer: A device delivering alternating current at a frequency which differs from the frequency of the supply current.

Full-Wave Rectifier: A rectifier so arranged as to rectify and render available all successive half cycles of an alternating current.

Fundamental of an Antenna: The lowest frequency of free alternating current in an unloaded antenna. (No series inductance or capacity.)

Fundamental Wave Length: The wave length corresponding to the lowest frequency of free alternating current which may exist in any circuit in which oscillations are possible.

Grid Leak Resistor: (Usually called a grid-leak.) A resistor connected between the filament and the grid of a three-electrode tube used in association with a condenser to give the voltage between grid and filament a certain average negative value.

Ground Wire: A conductive connection to the earth.

Group Frequency: The number of trains of damped waves or current per second.

Note.—The term "group frequency" replaces the term "spark frequency."

(to be continued in October issue)

RADIO FORMULAS

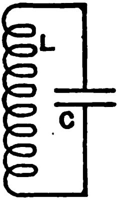

Fig. 1

f, frequency, in kilocycles.
λ, wavelength, in meters.
C, capacity, in microfarads (μf.).
L, inductance, in microhenries (μh.).
R, resistance, in ohms.
X, reactance, in ohms.
Z, impedance, in ohms.
E, electromotive force, in volts.
V, potential difference or voltage, in volts.
I, current, in amperes.
P, power, in watts.
ψ, phase difference of condensers, in degrees.
φ, phase angle of alternating current circuit.

Frequency of resonance in simple circuit.—

$$f = \frac{159.3}{\sqrt{LC}}, \quad \lambda = 1884\sqrt{LC}$$

Relation between wave length and frequency

$$f = 300{,}000/\lambda, \quad \lambda = 300{,}000/f$$

Capacity of parallel-plate air condenser (plates of any shape).—N = number of plates; S = area of plate in square inches; D = distance between plates in inches.

$$C = [224.6/10^9][(N-1)S/D]$$

The numerical value of 10^9 is 1,000,000,000.

Maximum capacity of variable condenser with semicular plates.—N and D as above; r_1 and r_2 = outside and inside radii respectively, of fixed plate, in inches.

$$C = \frac{353}{10^9}\,\frac{(N-1)(r_1^2 - r_2^2)}{D}$$

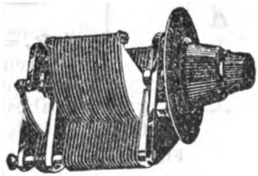

Fig. 2

Apparent Inductance, L_a, of a Coil having capacity.—

$$L_a = L(1 + 0.0000394f^2CL), \quad L_a = L\left(1 + 3{,}550{,}000\,\frac{CL}{\lambda^2}\right)$$

Inductance of single-layer coil.— n = number of turns; d = diameter of coil, in inches; l = overall length = number of turns $\times$ distance between centers of adjacent wires.

$$L = 0.01\,kn^2\frac{d^2}{l}$$

where k, for various values of the ratio of diameter to length, has the values given in table.

$\frac{d}{l}$	k
0.01	2.50
0.1	2.40
0.5	2.05
0.75	1.87
1.00	1.72
2.	1.32
3.	1.08
10.	0.51
100.	0.09

Table 1

Filter, Band Pass: A combination of electric circuits which present low attenuation to alternating currents of all frequencies between certain limiting border frequencies and comparatively high attenuation to alternating currents of all frequencies below the low limiting border frequency or above the upper limiting border frequency.

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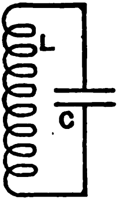
(to be continued in October issue)

RADIO FORMULAS



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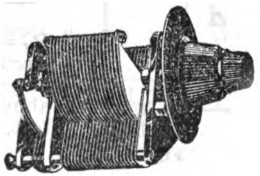
Maximum capacity of variable condenser with semi-cular plates.—N and D as above; r_1 and r_2 = outside and inside radii respectively, of fixed plate, in inches.

$$C = \frac{353}{10^9}\,\frac{(N-1)(r_1^2-r_2^2)}{D}$$



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Inductance of single-layer coil.— n = number of turns; d = diameter of coil, in inches; l = overall length = number of turns × distanco between centers of adjacent wires.

$$L = 0.01\,kn^2\frac{d^2}{l}$$

where k, for various values of the ratio of diameter to length, has the values given in table.

$\frac{d}{l}$	k
0.01	2.50
0.1	2.40
0.5	2.05
0.75	1.87
1.00	1.72
2.	1.32
3.	1.08
10.	0.51
100.	0.09

Table 1

Frequency of resonance of coil.—For a single-layer coil as above with condenser of capacity C connected to it, (see Fig. 1).

$$f = \frac{1593}{nd}\sqrt{\frac{l}{kC}} \quad , \quad \lambda = 188\,nd\sqrt{\frac{kC}{l}}$$

Inductance of multi-layer coil.—n = number of turns; d = average diameter of coil, in inches; l = length, in inches; c = depth of winding, in inches (see figure 3); k = constant in table 1; A = constant given below.

$$L = 0.01\,\frac{kn^2d^2}{l} \times 0.0064\,(0.693 + A)\,\frac{n^2d^2c}{l}$$

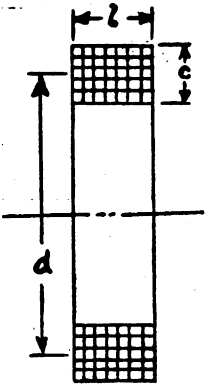


Fig. 3

$\frac{C}{l}$	A
1	0.000
2	0.120
3	0.175
5	0.229
10	0.279
20	0.310
30	0.322

Table 2

Current in receiving antenna (ordinary open type).—I_s = current in sending antenna of ordinary open type; d = distance between sending and receiving stations, in miles; R_r = resistance of receiving antenna circuit; h_s and h_r = average heights of sending and receiving antennas above ground or counterpoise, in feet.

$$I_{ra} = 3.63\,\frac{h_sh_rfI_s}{R_rd} \times 10^{-8} = 0.0109\,\frac{h_sh_rI_s}{R_r\lambda d}$$

Current in receiving coil antenna.—For plane of coil antenna parallel to line between sending and receiving stations, and for h_r = length of vertical side of coil antenna, in feet; l = length of horizontal side of coil antenna, in feet; N_r = number of turns of coil antenna; other symbols as in the two formulas just preceding.

$$I_{rc} = 2.32\,\frac{h_sh_rl_rN_rf^2I_s}{R_rd} \times 10^{-13}$$

Correction factor for long distances. over about 50 miles.—Multiply any of the preceding four formulas by

$$2.718^{-0.00014d/\sqrt{f}} \qquad \text{or } 2.718^{-0.076d/\sqrt{\lambda}}$$

Correction factor for angle α between plane of coil antenna and line between sending and receiving stations.—Multiply any of formulas for current in receiving antenna by cosine ω.

Voltage across antenna inductance.—

$$V = 0.00628fLI = 1884\ \frac{LI}{\lambda}$$

Power input in sending antenna.—R_s = resistance of sending antenna circuit.

$$P_s = R_s I_s^2$$

Inductance of ordinary open type antenna (unloaded). —L_a = total inductance; L_h = inductance of horizontal portion; L_v = inductance of vertical portion.

$$L_a = (L_h + L_v)/3$$

Capacity of ordinary open type antenna (unloaded).— C_a = total capacity; C_h = capacity of horizontal portion; C_v = capacity of vertical portion.

$$C_a = C_h + C_v$$

Inductance of antenna loaded with inductance.— L_e = inductance of loading coils; other symbols as above; L = total inductance of antenna circuit.

$$L = L_a + L_e$$

Capacity of antenna with series condenser.—C_s = capacity of series condenser; C = total capacity of antenna circuit. Other symbols as above.

$$C = (C_a C_s)/(C_a + C_s)$$

Natural (fundamental) frequency of unloaded antenna.—

$$f = \frac{159.3}{\sqrt{L_a C_a}},\ \lambda = 1884\sqrt{L_a C_a}$$

Frequency of antenna with loading inductance.—L_e = inductance of loading coils.

$$f = \frac{159.3}{\sqrt{(L_a + L_e)C_a}},\ \lambda = 1884\sqrt{(L_a + L_e)C_a}$$

Frequency of antenna with series condenser.—C_s = capacity of series condenser.

$$f = \frac{159.3}{\sqrt{L_a\ \dfrac{C_a C_s}{C_a + C_s}}} \text{ and } \lambda = 1884\sqrt{L_a\ \frac{C_a C_s}{C_a + C_s}}$$

Radiation resistance of antenna.—h = height of antenna to center of capacity; h, in feet.

$$R = 16.3\ h^2 f^2 \times 10^{-10},\quad R = 147\ (h^2/\lambda^2)$$

Current in a series circuit.—

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + \left(0.00628fL - \dfrac{159.3}{fC}\right)^2}}$$

Reactance of the capacity in a circuit.—

$$X_c = -\frac{159.3}{fC} = -0.000531\frac{\lambda}{C}$$

Reactance of the inductance in a circuit.—

$$X_L = 0.00628fL = 1884\ (L/\lambda)$$

Reactance of a series circuit.— $X = X_c + X_L$

Impedance of a series circuit.—$Z = \sqrt{R^2 + X^2}$

Capacities in parallel.—$C\ (\text{total}) = C_1 + C_2 + \dots$

Capacities in series.— $\frac{1}{C_1(\text{total})} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

Inductances in series.—$L(\text{total}) = L_1 + L_2 + \dots$

Inductances in parallel.— $\frac{1}{L\ (\text{total})} = \frac{1}{L_1} + \frac{1}{L_2} + \dots$

Resistances in series.—$R\ (\text{total}) = R_1 + R_2 + \dots$

Resistances in parallel.—$\frac{1}{R}\ (\text{total}) = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

Ohm's law.—When the current flowing in a series circuit is not alternating or pulsating, or does not in any way vary in magnitude or direction, it is said to be direct-current and the reactance X is equal to zero. This is likewise the case when a circuit containing inductance capacity and resistance, is tuned or in resonance with an impressed alternating emf. The above formulas then reduce to Ohm's law, viz., $I = E/R$

Power loss in a circuit.—V = difference of potential or voltage drop between any two points in a circuit between which the power loss is to be determined.

$$P = RI^2 = V^2/R$$

Direct current resistance of a copper conductor.— A = cross section of conductor, in square inches; l = length of conductor, in inches. ($10^{-9} = 0.000\ 000\ 001$)

$$R_0 = 62\ (l/A) \times 10^{-9}$$

Direct current resistance of round copper wire.— d = diameter of wire, in inches; l = length of wire, in feet

$$R = 85.2\ (l/d^2) \times 10^{-8}$$

Phase angle of circuit.—$\tan \varphi = X/R$

Power factor.—The power factor is defined as the cosine of the phase angle. power factor = $\cos \varphi = R/Z$

Condenser phase difference.—

$$\psi = 0.36rfC = 108{,}000\ rC/\lambda$$

Power input to a condenser.—$P = 0.0005\,fCE^2$

Power loss in condenser.—

$$P = EI\psi\ \text{(small air condensers)} = EI\cos\varphi$$

SUPPLEMENTAL LIST OF BROADCASTING STATIONS TO SEPTEMBER 1, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFAN	The Electric Shop........	Moscow, Idaho.....	833	360	50
KFRA	Marvin S. Olson..........	Carver, Minn.......	1250	240	100
KFRB	Hall Brothers............	Beeville, Tex.......	1210	248	250
KFRC	Radioart Studio..........	San Francisco, Calif.	1070	280	5
WBBA	Plymouth Congregational Church................	Newark, Ohio......	1250	240	20
WEBL	Radio Corp. of America...	United States (portable)............	1330	226	100
WEBO	Radio Company..........	Hamilton, Ohio....	1200	250	5
WFBI	Galvin Radio Supply Co...	Camden, N. J......	1270	236	100

Changes

KFDY—1100 kilocycles, 273 meters, 100 watts.
KFGD—power decreased to 100 watts.
KFLV—Swedish Evangelical Mission Church.
WABP—power increased to 200 watts.
WCAG—power decreased to 50 watts.
WDBJ—power increased to 50 watts.
WEAA—power increased to 50 watts.
WEB—power decreased to 100 watts.
WGAZ—1090 kilocycles, 275 meters.
WGR—Federal Telephone Mfg. Co.
WHAV—power increased to 100 watts.
WJY—power increased to 750 watts.
WMAK—Lockport Board of Com'rce.
WQAN—power increased to 100 watts.
WQJ—Calumet Rainbo Broadcasting Co.

Licenses Recently Cancelled

KFID KFPB WDBA WLAW

ARGENTINE BROADCASTING STATIONS

Captain Luis F. Orlandini, Chief Naval Communication Service has reported the following stations now in operation.

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
LOR	Radio Argentina..........	Buenos Aires.......	750	400	1500
LOV	F. Brusa.................	Buenos Aires.......	857	350	500
LOW	Grand Splendid..........	Buenos Aires.......	923	325	1000
LOX	Radio Cultura...........	Buenos Aires.......	800	375	500
LOY	Radio Nacional..........	Buenos Aires.......	923	325	1000
LOZ	Radio South America.....	Monte Grande.....	706	425	500

Foreign Stations

Radio broadcasting is now receiving the sanction and assistance of the government in almost all important countries. It is expected that because of the differences in national traits many unique and interesting plans will be put into effect.

We are in touch with the official sources of information in all countries and will describe anything of interest that comes to our attention through this channel.

If any of our distant readers can supplement our official reports with comments on the public's viewpoint we will indeed be glad to hear from them.

FADS IN RADIO

The era of circuits is closing and we are now entering upon one of low-loss design, and short waves. The two go hand in hand. We cannot hope to accomplish any improvements in transmission on short waves unless we design our circuits to have less resistance than they used to have.

It seems that necessity is the mother of invention, in this case as well as in any other. The great necessity for low-loss circuits was not noticed until experiments were started with the short waves. When it was found that good radiation could not be obtained on these short wave lengths in the ordinary circuits on account of the abnormal increase of resistance attending the enormous increase in frequency, we found that it would be worth while to reduce the circuit resistance.

The advantage of low-loss circuits in the broadcasting range of wave lengths should not be left unnoticed, however. It is obvious that the circuit resistances do not climb to such heights at these lower frequencies, but it still climbs high enough to cause considerable lowering of efficiency of reception.

We have tried several circuits whose design was directed mainly toward lowering the resistance of the oscillating circuits, and the results obtained fell hardly short of remarkable. In these circuits, the most serious offender of all the apparatus used were the coils. We wish to emphasize the great need for low-resistance coils. We have our low-loss condensers—very good ones at that. We also urge experimenters to investigate the relative importance of coil capacity, skin-effect, and ordinary ohmic resistance. It is our opinion that the most serious cause of coil resistance is the skin-effect, rather than the coil capacity especially in single-layer coils.

The skin-effect, however, is that of a mere multiplication of the ohmic resistance. There is reason to believe that by proper design the ohmic resistance of a coil might be so reduced that this reduction would far over-balance the attendent increase in the skin-effect. For example, if the ohmic resistance of the coil be reduced to one-fourth what it was, and the skin-effect should happen to be doubled at the same time, the final resistance of the coil would still be one-half what it was.

These remarks are made with the idea of giving our readers, many of them whom are experimenters, some ideas to work upon. The field is big and many opportunities are offered for exercising the ingenuity. The need is great also. We urge our readers to let us have their ideas on the subject, so that together we may so improve coil design that their resistances are brought down as low as the resistances of condensers.

DEFINITION OF RADIO TERMS

(*Continued from the September Radiofax*)

Harmonics: Multiples of the fundamental frequency which are often set up in a circuit; the introduction of these introduces elements into speech sounds which cause distortion. Part of the electrical energy is lost in setting up these harmonics. Harmonics which are present in the original speech sounds however must be preserved so that the quality is not altered.

Henry: The unit of inductance. One millionth of a henry, called the microhenry, is commonly used in radio calculations.

Heterodyne Reception: A method of radio reception for continuous waves, employing the principle of reaction between locally generated oscillations and incoming oscillations. See Beat Frequency.

Heterodyne, Self: See Self-Heterodyne.

Hot Wire Ammeter, Expansion Type: An ammeter dependent for its indications on the change in dimensions of an element heated by a current through it.

Hydrometer: An instrument for measuring the specific gravity of electrolytes in batteries.

Inductance: A property of conductors and circuits by virtue of which opposing emf's are induced in them or in other nearby circuits, due to the magnetic fields set up by the current cutting across these circuits.

Impact Transmitter: A radio transmitting set in which the transfer of energy from the exciting to an oscillatory circuit is effected during one pulse of the exciting circuit current.

Impedance: Ratio of voltage to current in an alternating-current circuit. Impedance is a factor determining the magnitude of current flow in a circuit. The greater the impedance for a given voltage the smaller the current. For series resistance and reactance it is equal to $\sqrt{(\text{Resistance})^2 + (\text{Reactance})^2}$

Impulse Emf.: An emf. the maximum value of which is large compared with its average value, the average value being taken over a time equal to the time-constant of the circuit in which the emf. is impressed.

Impulse Excitation: A method of producing free oscillations in a circuit in which the duration of the impressed voltage is short compared with the duration of the current produced.

Inductive Coupling: The association of one circuit with another by means of inductance common or mutual to both. (This term when used without modifying words is commonly used for coupling by means of mutual inductance, whereas coupling by means of self-inductance common to both circuits is called "direct inductive coupling.")

Inductive Reactance: That part of the impedance which is due to the presence of inductance in the circuit, and which is equal to 6.28×frequency×inductance.

Input Reactance of a Three-Electrode Tube: The reactance of an electron tube to its input circuit, due to its electrode capacities. (See reactance.) The ratio of an alternating sine-wave input voltage to the portion of the resulting input current which is an alternating sine-wave current of the same frequency as the input voltage and ninety degrees out of phase with it.

Inductance: That property of an electric circuit by virtue of which a varing current induces an emf in that circuit or in a neighboring circuit. Ratio of the magnetic flux to the current producing it.

Inductor: A conductor having inductance, usually a coil of wire.

Input Resistance of a Three-Electrode Tube; That part of the resistance of the input circuit of an electron tube which is due to the presence of the tube in the circuit. The ratio of an alternating sine-wave input voltage to that portion of the resulting input current which is an alternating sine-wave current of the same frequency as the input voltage and in phase with it.

Interrupted Continuous Waves: Interrupted continuous waves (I C W) are waves obtained by the modulation at audio frequency, during signaling, of an otherwise continuous wave.

Inverted L Antenna: A flat-top antenna in which the down lead is taken from one end of the horizontal portion.

Key: A device for closing and opening transmitting circuits in the act of transmitting signals.

Kenotron: A two element electron tube highly evacuated, generally used for rectifying alternating currents.

Lead-In: See Down Lead.

Lightning Arrester: An instrument placed in antenna circuits to furnish an easy path to ground for lightning or other extremely high voltage discharges.

Loading Coil: An inductor used to decrease the resonance frequency of an antenna or other circuit.

Logarithmic Decrement: The Napierian logarithm of the ratio of two successive current amplitudes in the same direction, for an exponentially damped alternating current. The logarithmic decrement can also be considered as a constant of a simple radio circuit, being π times the product of the resistance by the square root of the ratio of the capacity to the inductance of the circuit.

Loop Antenna: See Coil Antenna. Commonly used for a coil antenna of a single turn.

Loud Speaker: A device with or without special amplifying circuits, by means of which received sounds are made audible without the use of telephone receivers held to the ears.

Megohm: One million ohms. The unit of high resistance.

Meter: A unit of length, 39.37 inches.

Meter-Amperes: The product of the antenna current in amperes at the point of maximum current and the antenna height in meters for any radio transmitting station. It constitutes a factor for indicating the radiating strength of radio transmitting stations.

Microampere: One millionth of an ampere.

Microfarad: One millionth of a farad, a unit of capacity.

Microhm: One-millionth of an ohm.

Micromicrofarad: One millionth of a microfarad, a convenient unit of capacity.

Microhenry: One millionth of a henry.

Milliampere: One-thousandth of an ampere; a convenient unit in measuring small currents.

Modulation: Variation of amplitude of a radio-frequency current.

Modulation, Double: See Double Modulation.

Modulation Frequency Ratio: The ratio of modulation frequency to wave frequency.

Multiple-Tuned Antenna: An antenna with connections to ground through inductances at more than one point, the inductances being so determined that their reactances in parallel present a total reactance equal to that necessary to give the antenna the desired natural frequency.

Mutual Inductance: The inductive effect due to the proximity of two separate electrical circuits.

Ohm: The unit of resistance. The resistance of a d-c. circuit when a current of one ampere flows under a difference of potential of one volt is one ohm.

Open-Antenna: See Condenser Antenna.

Oscillations: (In Radio Work.) See Damped Alternating Current.

Output Resistance of Three-Electrode Tube: That part of the impedance of the output circuit of the tube which is due to the presence of the tube in the circuit.

Parallel Resonance: When a single lumped capacity and a single lumped inductance are connected in parallel between terminals to which an alternating emf. is applied, and the inductance or capacity or frequency is varied, the condition of parallel resonance exists when the current supplied by the source is a minimum.

Every part of every actual circuit possesses a certain amount of distributed capacity and inductance, and in practice complex arrangements of a considerable number of inductances and capacities are often used. For this reason the assumption as to a single lumped capacity and a single lumped inductance made in the above two definitions are not strictly realized in practice, and the resonance conditions attained are a combination of series resonance and parallel resonance. This is particularly true in circuits of radio frequency in which the

reactances due to leads and other parts of the circuit may be appreciable factors. (See Series Resonance.)

Period: The time of a complete cycle of alternating current or voltage; equal to 2 alternations.

Phase Difference: A quantity proportional to the power loss in a condenser or insulating material. Phase difference in degrees = 0.57 × power factor in per cent.

Plate Condenser Antenna: A condenser antenna in which the capacity areas consist of wires or metal plates, both elevated well away from the ground.

Plate Current: The current passing between the plate and the heated cathode in a three-electrode tube.

Pliotron: A kenotron with an additional electrode called the grid, for controlling the output current.

Potentiometer: Known also as a "voltage divider." A resistance used for obtaining adjustable voltages by utilizing the voltage drop in the resistance.

Power Factor: In a-c. circuits, the ratio of the power in watts to the volt-amperes, often expressed in percent.

Pulsating Current: A periodic current (that is, current passing through the successive equal cycles of values), the average value of which is not zero. A pulsating current is the sum of an alternating and a direct current.

Radiation Efficiency: The radiation efficiency of an antenna at a given wave length is the ratio of power radiated to the total power delivered to the antenna.

Radiation Resistance: The ratio of the total power radiated by an antenna to the square of the effective current at the point of maximum current.

Radio Channel: A band of wave lengths or frequencies of a width sufficient to permit of its use for radio communication without the radiation of subsidiary waves of more than a certain intensity at wave lengths or frequencies outside of such band.

Radio Frequencies: (See also Audio Frequencies.) The frequencies higher than those corresponding to normally audible sound waves.

Note.—It is not implied that radiation cannot be secured at lower frequencies, nor that radio frequencies are necessarily above the limit of audibility.

Radiogoniometer: See Direction Finder.

Reactance: That part of the impedance of a circuit due to the inductance and capacity in it. (See Impedance. Inductive reactance = 0.00628 × frequency × inductance. Capacitive reactance = —159.3 ÷ (frequency × capacity.) Frequency in kilocycles.

Rectification: Changing an alternating current into direct or pulsating current.

Rectifier: A device for rectifying alternating currents.

Regenerative Coupling: (See Feed-Back Coupling.) A receiving system designed to increase amplification in a three-electrode tube.

Resistance: The opposition offered to the flow of current in a circuit which manifests itself in the evolution of heat in the conductors.

Resistor: A device having resistance, used to introduce resistance into a circuit.

Resistive Coupling: The association of one circuit with another by means of resistance common to both.

Resonance: That condition of an a-c. circuit under which maximum current flows for a given voltage. In a series circuit there is resonance when the inductive reactance is equal to the capacitive reactance.

Rheostat: A resistor with a means for varying the resistance, to control the flow of current in the circuit in which the rheostat is connected.

Self-inductance: A property of wires and coils, due to the magnetic lines of force created by the current in the wire, cutting back on the wires and inducing an opposing emf in them.

Self-Heterodyne: A system of reception of continuous wave signals by the production of audio-frequency beats through the use of a device which is both a radio-frequency generator and a detector of the audio-frequency beat currents produced.

Series Resonance: When a single lumped capacity and a single lumped inductance are connected in series between terminals to which an alternating emf. is applied, and the inductance or capacity or frequency is varied, the condition of series resonance (maximum current) exists when the inductive reactance equals the capacitive reactance. (See parallel resonance.)

Signal Stray Ratio: See Strays.

Static: Static is conduction or charging current in the antenna system resulting from physical contact between the antenna and charged bodies (e. g., snowflakes) or masses of gas.

Stopping Condenser: A condenser used to provide direct-current insulation, but which permits alternating current to flow in a circuit.

Strays: Electromagnetic field causing disturbances in radio reception other than those produced by radio transmitting systems or by alternating current induction from wire circuits. The term "strays" includes atmospheric disturbances and disturbances caused by electrical apparatus such as sparking commutators; sparking contacts in fire alarm apparatus, Tirrell regulators or elevator controllers; sudden current changes through arc lamps; transient or sparking grounds on power systems; electric ignition systems of internal combustion engines, or sparking at third-rail or trolley contactors. (A reduction of the effect of strays on radio reception increases the signal-stray ratio.)

T-Antenna: A flat-top antenna in which the down lead is taken from the center of the horizontal portion.

Three-Electrode Tube: A combination of a heated cathode, a relatively cold anode, and a third electrode for controlling the current flowing between the other two electrodes, the whole contained within an enclosure evacuated to a low pressure.

This device is variously known as an Audion, Audiotron, Aerotron, Electron Relay, Electron Tube, Pliotron, Triode, Oscillion, Radiotron, etc.

Tickler: See Feed-Back Coil.

Transformer: A device consisting of one coil of wire placed in proximity with another, for the purpose of coupling two circuits together by virtue of the mutual inductance between the two coils. Also used for raising or lowering alternating voltages and currents. When the voltage of a line is increased by a transformer the current is correspondingly decreased and vice-versa. The power remains the same except for losses in the transformer. In this case one coil is wound directly upon the other. The coil connected to the source of power is called the **primary** and the other coil the **secondary.**

Umbrella Antenna: An antenna the conductors of which form elements of a cone with the apex at the top to which the down lead is connected.

Undamped Alternating Current: A periodic current (i.e., current passing through successive equal cycles of values) with constant amplitude whose average value is zero.

Volt: See electromotive force.

Volt-Ampere: The product of the current and voltage in a circuit.

Watt: A unit of power; $^1/_{746}$th of a horsepower 1000th of a kilowatt. A d.c. circuit carrying a current of one ampere with an emf. of one volt can deliver one watt of power.

Wave Antenna: A horizontal antenna the physical length of which is approximately equal to the length of signaling waves to be received, and which is so used as to be strongly directional.

Wave-Length: The ratio of the velocity of propagation of electric waves to the frequency.

Wavemeter: An instrument for measuring frequency and wavelength.

Waves, Continuous, Key Modulated: See Continuous Waves, Key Modulated.

Waves, Continuous, Modulated at Audio Frequency: See Continuous Waves at Audio Frequency.

Wave-Trap: A device used with a receiving set to improve its selectivity. A commonly used type is a parallel combination of a condenser and an inductor connected in series with the antenna. (See parallel resonance).

LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Corrected to October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse E. & M. Co.	East Pittsburgh, Pa.	920	326	1000
KDPM	Westinghouse E. & M. Co.	Cleveland, Ohio....	1110	270	500
KDPT	Southern Electrical Co.....	San Diego, Calif....	1230	244	100
KDYL	Newhouse Hotel..........	Salt Lake City, Utah	833	360	100
KDYM	Savoy Theatre...........	San Diego, Calif....	1070	280	50
KDYQ	Oregon Inst. of Technology	Portland, Ore.......	833	360	50
KDZB	Frank E. Siefert..........	Bakersfield, Calif....	1250	240	100
KDZE*	The Rhodes Dept. Store...	Seattle, Wash......	1110	270	100
KDZR	Bellingham Publishing Co.	Bellingham, Wash...	1150	261	50
KFAD	McArthur Bros. Co........	Phoenix, Ariz.......	833	360	100
KFAE	State College of Wash.....	Pullman, Wash.....	910	330	500
KFAF	Western Radio Corp......	Denver, Colo.......	1080	278	500
KFAJ	University of Colorado.....	Boulder, Colo.......	1150	261	100
KFAN	The Electric Shop........	Moscow, Idaho.....	833	360	50
KFAR	Studio Lighting Service Co.	Hollywood, Calif....	1070	280	150
KFAW	The Radio Den..........	Santa Ana, Calif....	1070	280	10
KFAY	W. J. Virgin.............	Medford, Ore.......	1060	283	50
KFBB	F. A. Buttrey & Co.......	Havre, Mont........	833	360	100
KFBC	W. K. Azbill.............	San Diego, Calif....	1080	278	5
KFBE	Reuben H. Horn.........	San LuisObispo,Cal.	1240	242	50
KFBG	First Presbyterian Church.	Tacoma, Wash.....	833	360	50
KFBK	Kimball-Upson Co........	Sacramento, Calif...	1060	283	100
KFBL	Leese Bros...............	Everett, Wash......	1340	224	10
KFBS	Trinidad Gas & Electric Supply Co.& Chronicle News Publishing Co.....	Trinidad, Colo......	1070	280	10
KFBU	Bishop N. S. Thomas.....	Laramie, Wyo......	1060	283	50
KFCB	Nielson Radio Supply Co..	Phoenix, Ariz.......	1260	238	10
KFCF	Frank A. Moore..........	Walla Walla, Wash.	833	360	100
KFCL	Leslie E. Rice............	Los Angeles, Calif...	1270	236	500
KFCP	Ralph W. Flygare........	Ogden, Utah.......	833	360	25
KFCV	Fred Mahaffey, Jr........	Houston, Tex.......	833	360	10
KFCZ	Omaha Central H. S......	Omaha, Nebr.......	1160	259	50
KFDD	St. Michael Cathedral.....	Boise, Idaho.......	1190	252	10
KFDH	University of Arizona.....	Tucson, Ariz.......	1120	268	50
KFDJ	Oregon Agri. College......	Corvallis, Ore......	833	360	50
KFDL	Knight Campbell MusicCo.	Denver, Colo.......	1330	225	5
KFDX	First Baptist Church......	Shreveport, La.....	833	360	100
KFDY	S. Dak. State College.....	Brookings, S. Dak..	1100	273	100
KFDZ	Harry O. Iverson..........	Minneapolis, Minn..	1300	231	5
KFEC	Meier & Frank Co........	Portland, Ore.......	1210	248	50
KFEL	Winner Radio Corp.......	Denver, Colo.......	1180	254	150
KFEQ	J. L. Scroggin............	Oak, Nebr.........	1120	268	100
KFER	Auto. Elec. Service Co.....	Fort Dodge, Iowa..	1300	231	10
KFEX	Augsburg Seminary.......	Minneapolis, Minn..	1150	261	100
KFFB	Jenkins Furniture Co......	Boise, Idaho.......	1250	240	10
KFFE	Eastern Oregon Radio Co..	Pendleton, Ore.....	833	360	10
KFFP	First Baptist Church......	Moberly, Mo........	1130	265	50
KFFR	Nevada State Journal.....	Sparks, Nev........	1330	225	10
KFFV	Graceland College........	Lamoni, Iowa......	1070	280	100
KFFY	Pincus & Murphey.......	Alexandria, La......	1090	275	50
KFGC	Louisiana State Univ......	Baton Rouge, La....	1180	254	100
KFGD	Chickasha Rad. & Elec. Co.	Chickasha, Okla....	1210	248	100
KFGH	Leland Stanford University	Stanford Univ.,Calif	1100	273	500
KFGL	Arlington Garage.........	Arlington, Ore......	1280	234	5
KFGQ	Crary Hardware Co.......	Boone, Iowa.......	1330	225	10
KFGX	First Presbyterian Church.	Orange, Tex........	1200	250	500
KFGZ	Emmanuel Missionary Col.	Berrien Sprgs.Mich.	1050	286	500
KFHA	Western State Col. of Colo.	Gunnison, Colo.....	1190	252	50
KFHD	Utz Electric Co...........	St. Joseph, Mo.....	1330	225	100

*This Company also operates station KFOA

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFHJ	Fallon & Company	Santa Barbara, Calif.	833	360	100
KFHR	Star Elec. & Radio Co.	Seattle, Wash.	1140	263	100
KFI	Earle C. Anthony (Inc.)	Los Angeles, Calif.	640	469	500
KFIF	Benson Polytechnic School	Portland, Ore.	833	360	100
KFIO	North Central H. S.	Spokane, Wash.	1190	252	50
KFIQ	First Methodist Church	Yakima, Wash.	1240	242	50
KFIU	Alaska Elec. Light & Power Co.	Juneau, Alaska	1330	225	10
KFIX	Reorganized Church of Jesus Christ of Latter Day Saints	Independence, Mo.	1250	240	250
KFIZ	Daily Commonwealth and Siefert Radio Corp.	Fond du Lac., Wis.	1100	273	100
KFJB	Marshall Elec. Co.	Marshalltown, Iowa	1210	248	10
KFJC	Seattle Post-Intelligencer	Seattle, Wash.	1110	270	100
KFJF	Nation Radio Mfg. Co.	OklahomaCity, Okla.	1190	252	20
KFJI	Liberty Theatre—E. E. Marsh	Astoria, Ore.	1190	252	10
KFJK	Delano Radio & Elec. Co.	Bristow, Okla.	1280	234	100
KFJM	Univ. of North Dakota	Grand Forks, N. D.	1070	280	100
KFJQ	Valley Radio Div. of Elec. Constr. Co (Portable)	Grand Forks, N. D.	1070	280	5
KFJR	Ashley C. Dixon & Son	Stevensville, Mont.	1160	259	50
KFJX	Iowa State Teachers Col.	Cedar Falls, Iowa	1070	280	50
KFJY	Tunwall Radio Co.	Ft. Dodge, Iowa	1220	246	50
KFJZ	Texas National Guard 112th Cavalry	Ft. Worth, Tex.	1180	254	20
KFKA	Colo. State Teachers Col.	Greeley, Colo.	1100	273	50
KFKB	Brinkley-Jones Hospital Assn.	Milford, Kansas	1050	286	500
KFKQ	Conway Radio Labs	Conway, Ark.	1200	250	100
KFKV	F. F. Gray	Butte, Mont.	1060	283	50
KFKX	Westinghouse E. & M. Co.	Hastings, Nebr.	1030	291	1000
KFKZ	Nassour Bros. Radio Co.	ColoradoSprgs, Colo.	1280	234	10
KFLA	Abner R. Wilson	Butte, Mont.	1060	283	5
KFLB	Signal Electric Mfg. Co.	Menominee, Mich.	1210	248	50
KFLE	National Edu. Service	Denver, Colo.	1120	268	25
KFLQ	Bizzell Radio Shop	Little Rock, Ark.	1150	261	20
KFLR	Univ. of New Mexico	Albuquerque, N. Mex	1180	254	100
KFLU	Rio Grande Radio Supply House	San Benito, Tex.	1270	236	15
KFLV	Swedish Evangelical Mission Church	Rockford, Ill.	1310	229	100
KFLW	Missoula Elec. Supply Co.	Missoula, Mont.	1280	234	10
KFLX	George Roy Clough	Galveston, Texas	1250	240	10
KFLZ	Atlantic Automobile Co.	Atlantic, Iowa	1100	273	100
KFMB	Christian Churches of Little Rock	Little Rock, Ark.	1180	254	50
KFMQ	Univ. of Arkansas	Fayetteville, Ark.	1140	263	100
KFMR	Morningside College	Sioux City, Iowa	1150	261	10
KFMT	Dr. Geo. W. Young	Minneapolis, Minn.	1300	231	5
KFMW	M. G. Sateren	Houghton, Mich.	1130	265	50
KFMX	Carleton College	Northfield, Minn.	1060	283	500
KFNF	Henry Field Seed Co.	Shenandoah, Iowa	1130	265	500
KFNG	Wooten's Radio Shop	Coldwater, Miss.	1180	254	10
KFNL	Radio Broadcast Ass'n	Paso Robles, Calif.	1250	240	10
KFNV	L. A. Drake Battery & Radio Supply Shop	Santa Rosa, Calif.	1280	234	5
KFNY	Montana Phonograph Co.	Helena, Mont.	1150	261	5
KFNZ	Royal Radio Company	Burlingame, Calif.	1300	231	10
KFOA*	The Rhodes Dept. Store	Seattle, Wash.	660	454	500
KFOC	First Christian Church	Whittier, Calif.	1270	236	100
KFOD	The Radio Shop	Wallace, Idaho	1340	224	10
KFOF	Rohrer Electric Co.	Marshfield, Ore.	1250	240	10

*This Company also operates station KDZE

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFOJ	Moberly H. S. Radio Club	Moberly, Mo.	1220	246	5
KFOL	Leslie M. Schafbuch	Marengo, Iowa	1280	234	5
KFON	Echophone Radio Shop	Long Beach, Calif.	1280	234	100
KFOO	Latter Day Saints Univ.	Salt Lake City, Utah	1150	261	10
KFOQ	O. William Chancellor	Galveston, Tex.	1250	240	50
KFOR	David City Tire & Elec.Co.	David City, Nebr.	1330	225	20
KFOT	College Hill Radio Club	Wichita, Kans.	1300	231	50
KFOU	Hommel Mfg. Co.	Richmond, Calif.	1180	254	160
KFOX	Board of Ed. Tech. H. S.	Omaha, Nebr.	1210	248	100
KFOY	Beacon Radio Service	St. Paul, Minn.	1330	225	50
KFOZ	LeonHudsonRealEstateCo.	Ft. Smith, Ark.	1290	232	20
KFPG	Garretson & Dennis	Los Angeles, Calif.	1260	238	100
KFPH	H. C. Mailander	Salt Lake City, Utah	1240	242	50
KFPL	C. C. Baxter	Dublin, Texas	1190	252	15
KFPM	The New Furniture Co.	Greenville, Texas	1240	242	10
KFPN	Missouri National Guard	Jefferson City, Mo.	1240	242	10
KFPO	Colorado National Guard	Denver, Colo.	1300	231	500
KFPP	G. & G. Radio & Elec. Co.	Olympia, Wash.	1270	236	20
KFPR	Los Angeles Co. Forestry Dept.	Los Angeles, Calif.	1300	231	500
KFPT	Cope & Johnson Co.	Salt Lake City, Utah	1120	268	500
KFPV	Heints & Kohlmoos, Inc.	San Francisco, Calif.	1270	236	50
KFPW	St. Johns M. E. Church	Carterville, Mo.	1120	268	10
KFPX	First Presbyterian Church	Pine Bluff, Ark.	1240	242	100
KFPY	Symons Investment Co.	Spokane, Wash.	1060	283	100
KFQA	The Principia	St. Louis, Mo.	1150	261	50
KFQB	The Searchlight Pub. Co.	Fort Worth, Tex.	1180	254	100
KFQC	Kidd Bros. Radio Shop	Taft, Calif.	1320	227	100
KFQD	Chovin Supply Co.	Anchorage, Alaska	1070	280	100
KFQE	Dickenson-Henry Radio Laboratories	Colo. Springs, Colo.	1340	224	5
KFQF	Donald A. Boult	Minneapolis, Minn.	1340	224	10
KFQG	So. Calif. Radio Ass'n.	Los Angeles, Calif.	1330	225	100
KFQH	Radio Service Co.	Burlingame, Calif.	1300	231	50
KFQI	Thos. H. Ince Corp.	Culver City, Calif.	1280	234	100
KFQJ	Harbour-Longmire Co.	Oklahoma City, Okla	1270	236	50
KFQK	Democrat Leader	Fayette, Mo.	1270	236	10
KFQL	Oklahoma Free State Fair Association	Muskogee, Okla.	1190	252	20
KFQM	Texas Highway Bulletin	Austin, Tex.	1120	268	100
KFQN	Third Baptist Church	Portland, Ore.	1060	283	5
KFQO	Meier Radio Shop	Russell, Kans.	1150	261	10
KFQP	Geo. S. Carson, Jr.	Iowa City, Iowa	1340	224	10
KFQR	Walter LaFayette Ellis	OklahomaCity, Okla.	1200	250	10
KFQS	Dickenson-Henry Radio L.	Manitou, Colo.	1220	246	10
KFQT	Texas National Guard	Denison, Tex.	1190	252	10
KFQU	W. Riker	Holy City, Calif.	1280	234	100
KFQV	Omaha Grain Exchange	Omaha, Nebr. (Portable)	1300	231	100
KFQW	C. F. Knieria	No. Bend, Wash.	1210	248	50
KFQX	Alfred M. Hubbard	Seattle, Wash.	1290	232	250
KFQY	Farmers State Bank	Belden, Nebr.	1100	273	10
KFQZ	Taft Radio Co.	Hollywood, Calif.	1250	240	250
KFRB	Hall Brothers	Beeville, Tex.	1210	248	250
KFRC	Radioart Studio	San Francisco, Calif.	1070	280	5
KFRF	W. R. Brown	Alexandria, La.	1240	242	10
KFRG	Cleveland High School	St. Louis, Mo.	1270	236	20
KFRH	The Radio Shop	Grafton, N.D.	1120	268	10
KFRI	The Reynolds Radio Co., Incorporated	Denver, Colo. (Portable)	1340	224	5
KFRJ	Guy Simmons, Jr.	Conway, Ark.	1200	250	10
KFSG	Echo Park Evangelistic Association	Los Angeles, Calif.	1280	234	500

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFSY	The Van Blaricom Co.	Helena, Mont.	1150	261	10
KGB	Tacoma Daily Ledger	Tacoma, Wash.	1190	252	50
KGG	Hallock & Watson Radio Service	Portland, Ore.	833	360	50
KGO	General Elec. Co.	Oakland, Calif.	960	312	1000
KGU	Marion A. Mulrony	Honolulu, Hawaii	833	360	250
KGW	Oregonian Publishing Co.	Portland, Ore.	610	492	500
KGY	St. Martins College	Lacey, Wash.	1160	259	5
KHJ	Times-Mirror Co.	Los Angeles, Calif.	760	395	500
KHQ	Excelsior Motorcycle & Bicycle Company	Seattle, Wash.	833	360	100
KJQ	C. O. Gould	Stockton, Calif.	833	360	5
KJR	Northwest Radio Serv. Co.	Seattle, Wash.	1060	283	50
KJS	Bible Inst. of Los Angeles	Los Angeles, Calif.	833	360	750
KLS	Warner Bros.	Oakland, Calif.	833	360	250
KLX	Tribune Publishing Co.	Oakland, Calif.	590	508	500
KLZ	Reynolds Radio Co., Inc.	Denver, Colo.	1060	283	250
KMJ	San Joaquin Lt.&P'rCorp.	Fresno, Calif.	1210	248	50
KMO	Love Electric Co.	Tacoma, Wash.	833	360	10
KNT	Walter Hemrich	Kukak Bay, Alaska.	1140	263	100
KNX	Los Angeles Eve. Express.	Los Angeles, Calif.	890	337	500
KOB	N. Mex. College of Agriculture and Mechanic Arts.	StateCollege,N.Mex.	833	360	500
KOP	Detroit Police Dept.	Detroit, Mich.	1050	286	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	710	422	500
KQP	Apple City Radio Club	Hood River. Ore.	833	360	10
KQV	Doubleday-HillElectricCo.	Pittsburgh, Pa.	1110	270	500
KQW	Charles D. Herrold	San Jose, Calif.	833	360	50
KRE	Berkeley Daily Gazette	Berkeley, Calif.	1090	275	50
KSD	Post-Dispatch	St. Louis, Mo.	550	545	500
KTW	First Presbyterian Church.	Seattle, Wash.	833	360	750
KUO	Examiner Printing Co.	San Francisco, Calif.	833	360	150
KUY	Coast Radio Co., Inc.	El Monte, Calif.	1170	256	50
KWG	Portable Wireless Telephone Co.	Stockton, Calif.	833	360	100
KWH	Los Angeles Examiner	Los Angeles, Calif.	833	360	500
KYQ	Electric Shop	Honolulu, Hawaii	1110	270	100
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	560	535	1000
KZM	Preston D. Allen	Oakland, Calif.	833	360	100
WAAB	Valdemar Jensen	New Orleans, La.	1120	268	100
WAAC	Tulane University	New Orleans, La.	833	360	100
WAAD	Ohio Mechanics Institute.	Cincinnati, Ohio.	833	360	25
WAAF	Chicago Daily Drovers Journal	Chicago, Ill.	1050	286	200
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAN	University of Missouri	Columbia, Mo.	1180	254	50
WAAW	Omaha Grain Exchange	Omaha, Nebr.	1050	286	500
WABB	Harrisburg Sporting Goods Co.	Harrisburg, Pa.	1130	265	10
WABD	Parker High School	Dayton, Ohio	1060	283	5
WABE	Y. M. C. A.	Washington, D.C.	1060	283	100
WABH	Lake Shore Tire Co.	Sandusky, Ohio	1250	240	10
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	100
WABL	Connecticut Agri. College.	Storrs, Conn.	1060	283	100
WABM	F. E. Doherty	Saginaw, Mich.	1180	254	100
WABN	Ott Radio, Inc.	La Crosse, Wis.	1230	244	500
WABO	Lake Ave. Baptist Church.	Rochester, N. Y.	1060	283	10
WABP	Robert Frederick Weinig.	Dover, Ohio	1130	265	200
WABQ	Haverford College Radio Club	Haverford, Pa.	1150	261	50
WABR	Scott High School (J.W.B. Foley)	Toledo, Ohio	1110	270	50
WABU	Victor Talking Machine Co.	Camden, N. J.	1330	225	50

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WABW	The College of Wooster, Physics Dept.	Wooster, Ohio	1280	234	20
WABX	Henry B. Joy	(near) Mt. Clemens, Mich.	1110	270	500
WABY	John Magaldi, Jr.	Philadelphia, Pa.	1240	242	50
WABZ	Coliseum Place Baptist Church	New Orleans, La.	1140	263	50
WAHG	A. H. Grebe & Co.	Richmond Hill, N.Y.	950	316	500
WBAA	Purdue University	West Lafayette, Ind.	1060	283	250
WBAK	Penn. State Dept. of Police	Harrisburg, Pa.	750	400	500
WBAN	Wireless Phone Corp.	Paterson, N. J.	1230	244	100
WBAO	James Millikin University	Decatur, Ill.	1090	275	50
WBAP	The Ft. Worth Star Telegram	Fort Worth, Tex.	630	476	1000
WBAV	Erner & Hopkins Co.	Columbus, Ohio	710	423	500
WBAX	John H. Stenger, Jr.	Wilkes-Barre, Pa.	1180	254	20
WBAY	Western Elec. Co.	NewYorkCity, N.Y.	610	492	500
WBBA	Plymouth Congreg. Church	Newark, Ohio	1250	240	20
WBBD	Barbey Battery Service	Reading, Pa.	1260	238	10
WBBF	Georgia School of Technology	Atlanta, Ga.	1110	270	500
WBBG	Irving Vermilya	Mattapoisett, Mass.	1210	248	500
WBBH	J. Irving Bell	Port Huron, Mich.	1220	246	50
WBBL	Grace Covenant Church	Richmond, Va.	1060	283	5
WBBP	Petoskey High School	Petoskey, Mich.	1220	246	100
WBBR	Peoples Pulpit Ass'n.	Rossville, N. Y.	1100	273	500
WBBT	Lloyd Bros.	Philadelphia, Pa.	1280	234	5
WBBU	Jenks Motor Sales Co.	Monmouth, Ill.	1340	224	10
WBBV	Johnstown Radio Co.	Johnstown, Pa.	1210	248	5
WBBW	Ruffner Junior H. S.	Norfolk, Va.	1350	222	50
WBBY	Washington Light Infantry Co. B, 118th Inf.	Charleston, S. C.	1120	268	10
WBBZ	Noble B. Watson	Indianapolis, Ind.	1320	227	50
WBL	T. & H. Radio Co.	Anthony, Kans.	1180	254	100
WBR	Penna. State Police	Butler, Penna.	1050	286	250
WBS	D. W. May (Inc.)	Newark, N. J.	833	360	10
WBT	Southern Radio Corp.	Charlotte, N. C.	833	360	250
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	890	337	1000
WCAD	St. Lawrence University	Canton, N. Y.	1070	280	250
WCAE	Kaufman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCAG	Clyde R. Randall	New Orleans, La.	1120	268	50
WCAH	Entrekin Electric Co.	Columbus, Ohio	1050	286	100
WCAJ	Nebraska Wesleyan Univ.	Univ. Place, Nebr.	1060	283	500
WCAK	Alfred P. Daniel	Houston, Texas	1140	263	10
WCAL	St. Olaf College, Physics Dept.	Northfield, Minn.	833	360	500
WCAO	Sanders & Stayman Co.	Baltimore, Md.	833	360	50
WCAP	Chesapeake & Potomac Telephone Co.	Washington, D.C.	640	469	500
WCAR	The Southern Radio Corp. of Texas	San Antonio, Tex.	833	360	100
WCAS	Dunwoody Industr.Inst.	Minneapolis, Minn.	1070	280	100
WCAT	S. Dak. State Sch. of Mines	Rapid City, S. Dak.	1250	240	50
WCAU	Durham & Co.	Philadelphia, Pa.	1050	286	250
WCAV	J. C. Dice Electric Co.	Little Rock, Ark.	833	360	10
WCAX	University of Vermont	Burlington, Vt.	833	360	50
WCAY	Milwaukee Civic Broadcasting Ass'n., Inc.	Milwaukee, Wis.	1130	265	250
WCBA	Chas. W. Heimbach	Allentown, Pa.	1070	280	5
WCBC	Univ. of Michigan	Ann Arbor, Mich.	1070	280	200
WCBD	Wilbur Glenn Voliva	Zion, Ill.	870	345	500
WCBE	Uhalt Radio Co.	New Orleans, La.	1140	263	5
WCBG	Howard S. Williams	Pascagoula, Miss. (Portable)	1120	268	10

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WCBH	Univ. of Mississippi	(near) Oxford Miss.	1240	242	10
WCBI	Nicell, Duncan & Rush	Bemis, Tenn.	1250	240	50
WCBJ	J. C. Maus	Jennings, La.	1230	244	10
WCBK	E. Richard Hall	St. Petersburg, Fla.	1130	265	500
WCBL	Northern Radio Mfg. Co.	Houlton, Me.	1070	280	50
WCBO	The Radio Shop, Inc.	Memphis, Tenn.	1200	250	20
WCBQ	First Baptist Church	Nashville, Tenn.	1270	236	100
WCBR	Charles H. Messter	Providence, R. I. (Portable)	1220	246	5
WCBT	Clark Univ. Collegiate Dept.	Worcester, Mass.	1260	238	250
WCBU	Arnold Wireless Supply Co.	Arnold, Pa.	1180	254	50
WCBV	Tullahoma Radio Club	Tullahoma, Tenn.	1190	252	10
WCBW	G. P. Rankin, Jr., & M. Solomon	Macon, Ga.	1330	225	10
WCBX	Radio Shop of Newark	Newark, N. J.	1290	232	10
WCBY	The Forks Elec. Shop	Buck Hill Falls, Pa.	1120	268	10
WCBZ	Coppotelli Bros. Music House	Chicago Heights, Ill.	1210	248	50
WCCO	Washburn Crosby Co.	Minneapolis, Minn.	720	417	500
WCK	Stix, Baer & Fuller Co.	St. Louis, Mo.	833	360	100
WCX	Detroit Free Press	Detroit, Mich.	580	517	500
WDAE	Tampa Daily Times	Tampa, Fla.	833	360	250
WDAF	The Kansas City Star	Kansas City, Mo.	730	411	500
WDAG	J. L. Martin	Amarillo, Tex.	1140	263	100
WDAH	Trinity Methodist Church	El Paso, Tex.	1120	268	100
WDAR	Lit Brothers	Philadelphia, Pa.	760	395	500
WDAS	Samuel A Waite	Worcester, Mass.	833	360	10
WDAU	Slocum & Kilburn	New Bedford, Mass.	833	360	100
WDAY	Radio Equip. Corp.	Fargo, N. Dak.	1230	244	50
WDBB	A. H. Waite & Co., Inc.	Taunton, Mass.	1310	229	10
WDBC	Kirk, Johnson & Co., Inc.	Lancaster, Pa.	1160	259	50
WDBD	Herman E. Burns	Martinsburg, W. Va.	1120	268	5
WDBF	Robert G. Phillips	Youngstown, Ohio	1220	246	50
WDBH	C. T. Scherer Co.	Worcester, Mass.	1120	268	100
WDBI	Radio Specialty Co.	St. Petersburg, Fla.	1330	225	10
WDBJ	Richardson & WaylandElec Corp.	Roanoke, Va.	1310	229	50
WDBL	Wisconsin Dept. of Markets	Stevens Points, Wis.	1080	278	500
WDBO	Rollins College, Inc.	Winter Park, Fla.	1250	240	50
WDBP	Superior State Normal School	Superior, Wis.	1150	261	50
WDBQ	Morton Radio Supply Co.	Salem, N. J.	1280	234	10
WDBR	Tremont Temple Baptist Church	Boston, Mass.	1170	256	100
WDBS	The S. M. K. Radio Corp.	Dayton, Ohio	1060	283	5
WDBT	Taylor's Book Store	Hattiesburg, Miss.	1270	236	10
WDBU	Somerset Radio Co.	Skowhegan, Me.	1160	259	10
WDBW	The Radio Den	Columbia. Tenn.	1120	268	20
WDBX	Otto Baur	New York. N. Y.	1290	232	5
WDBY	North Shore Cong. Church	Chicago, Ill.	1160	259	500
WDBZ	Boy Scouts of America	Kingston, N. Y.	1290	232	5
WDM	Grace Church of the Covenant	Washington, D.C.	1280	234	50
WDZ	James L. Bush	Tuscola, Ill.	1080	278	10
WEAA	Frank D. Fallain & (Police Dept.)	Flint, Mich.	1070	280	50
WEAF	American Tel. & Tel. Co.	New York City, N.Y.	610	492	1000
WEAH	Wichita Board of Trade	Wichita, Kans.	1070	280	100
WEAI	Cornell University	Ithaca, N. Y.	1050	286	500
WEAJ	Univ. of South Dakota	Vermillion, S.Dak.	1060	283	100
WEAM	Borough of No. Plainfield	N. Plainfield, N.J.	1050	286	150
WEAN	The Shepard Company	Providence, R. I.	1100	273	100
WEAO	Ohio State University	Columbus, Ohio	1020	294	500
WEAP	Mobile Radio Co., Inc.	Mobile, Ala.	833	360	100

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WEAR	Baltimore News and American Publishing Co.	Baltimore, Md.	1150	261	50
WEAU	Davidson Bros. Co.	Sioux City, Iowa	1090	275	100
WEAY	Iris Theatre	Houston, Tex.	833	360	500
WEB	Benwood Co., Inc.	St. Louis, Mo.	1100	273	100
WEBA	The Electric Shop	Highland Park, N. J.	1290	232	15
WEBC	Walter Cecil Bridges	Superior, Wis.	1240	242	10
WEBD	Electrical Equip.&Serv. Co.	Anderson, Ind.	1220	246	10
WEBE	Roy W. Waller	Cambridge, Ohio	1210	248	10
WEBH	Edgewater Beach Hotel Co.	Chicago, Ill.	810	370	500
WEBI	Walter H. Gibbons	Salisbury, Md.	1240	242	15
WEBJ	Third Ave. Ry. Co.	New York, N.Y.	1100	273	500
WEBK	Grand Rapids Radio Co.	Grand Rapids, Mich	1150	261	20
WEBL	Radio Corp. of America	U. S. (Portable)	1330	225	100
WEBO	Radio Company	Hamilton, Ohio	1200	250	5
WEBP	Spanish Fort Amusement Park	New Orleans, La.	1070	280	50
WEBQ	Tate Radio Co.	Harrisburg, Ill.	1330	225	10
WEBR	H. H. Howell	Buffalo, N. Y.	1250	240	15
WEBS	First Baptist Church	New Orleans, La.	1190	252	50
WEBT	The Dayton Co-operative Industrial High School	Dayton, Ohio	1110	270	5
WEBU	De Land Piano & Mus. Co.	DeLand, Fla.	1160	259	5
WEBW	Beloit College	Beloit, Wis.	1060	283	500
WEBX	John E. Cain, Jr.	Nashville, Tenn.	1140	263	50
WEBY	Hobart Radio Co.	Roslindale, Mass.	1330	225	10
WEBZ	Savannah Radio Corp.	Savannah, Ga.	1070	280	5
WEEI	The Edison Electric Illuminating Co.	Boston, Mass.	990	303	500
WEV	Hurlburt-StillElectrical Co.	Houston, Tex.	1140	263	100
WEW	St. Louis University	St. Louis, Mo.	1070	280	100
WFAA	Dallas News & Dallas Jour.	Dallas, Tex.	630	476	500
WFAB	Carl F. Woese	Syracuse, N. Y.	1280	234	100
WFAM	Times Publishing Co.	St. Cloud, Minn.	833	360	20
WFAN	Hutchinson Elec. Serv. Co.	Hutchinson, Minn.	1050	286	100
WFAV	University of Nebraska	Lincoln, Nebr.	1090	275	250
WFBB	Eureka College	Eureka, Ill.	1250	240	50
WFBG	Wm. F. Gable Co.	Altoona, Pa.	1150	261	100
WFBH	Concourse Radio Co.	New York, N.Y.	1100	273	500
WFBI	Galvin Radio Supply Co.	Camden, N.J.	1270	236	100
WFBJ	St. John's University	Collegeville, Minn.	1270	236	50
WFBK	Dartmouth College	Hanover, N.H.	1170	256	100
WFBL	Onondaga Hotel Co.	Syracuse, N.Y.	1050	286	100
WFBM	Merchants Heat&Light Co.	Indianapolis, Ind.	1120	268	250
WFBN	Radio Sales&Service Co.	Bridgewater, Mass.	1330	225	200
WFBW	Ainsworth-Gates Radio Co.	Cincinnati, Ohio	970	309	750
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGAL	Lancaster Electric Supply & Construction Col	Lancaster, Pa.	1210	248	50
WGAN	Cecil E. Lloyd	Pensacola, Fla.	833	360	50
WGAQ	Youree Hotel	Shreveport, La.	1190	252	150
WGAZ	South Bend Tribune	South Bend, Ind.	833	360	250
WGBS	Gimbel Brothers	New York, N.Y.	950	316	1000
WGI	Am. Rad. & Research Corp.	Medford Hillside, Mass.	833	360	100
WGL	Thos. F. J. Howlett	Philadelphia, Pa.	833	360	250
WGN	Chicago Tribune and Drake Hotel	Chicago, Ill.	810	370	500
WGR	Federal Tel. Mfg. Co.	Buffalo, N. Y.	940	319	750
WGY	General Electric Co.	Schenectady, N. Y.	790	380	1000
WHA	University of Wisconsin	Madison, Wis.	1090	275	500
WHAA	State Univ. of Iowa	Iowa City, Iowa	620	484	500
WHAD	Marquette University	Milwaukee, Wis.	1070	280	100
WHAG	Univ. of Cincinnati	Cincinnati, Ohio	1350	222	200

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WHAK	Roberts Hardware Co.....	Clarksburg, W. Va..	1260	238	15
WHAM	Univ. of Rochester.........	Rochester, N.Y.....	1060	283	100
WHAR	ParamountRadio&Elec.Co.	Atlantic City, N. J..	1090	275	100
WHAS	Courier-Journal & Louisville Times.............	Louisville, Ky......	750	400	500
WHAV	Wilmington Elec. Spec. Co.	Wilmington. Del....	833	360	100
WHAZ	Rensselaer PolytechnicInst.	Troy, N. Y.........	790	380	500
WHB	Sweeney Automotive and Electrical School........	Kansas City, Mo....	730	411	500
WHK	The Radiovox Co..........	Cleveland, Ohio....	1060	283	100
WHN	Loew's State Threatre Studio....................	New York, N.Y....	833	360	500
WHO	Bankers Life Co...........	Des Moines, Ia.....	570	526	500
WIAB	Art A. Johnson's Garage...	Rockford, Ill.......	1190	252	50
WIAC	Galveston Tribune........	Galveston, Tex.....	833	360	100
WIAD	Howard R. Miller.........	Philadelphia, Pa....	1180	254	100
WIAK	Journal-Stockman Co......	Omaha, Nebr........	1080	278	250
WIAS	Home Electric Co.........	Burlington, Iowa...	1060	283	100
WIK	K. & L. Elec. Co.	McKeesport, Pa....	1280	234	100
WIP	Gimbel Brothers..........	Philadelphia, Pa....	590	508	500
WJAB	American Elec. Co.........	Lincoln, Neb.......	1310	229	100
WJAD	Frank P. Jackson..........	Waco, Tex..........	833	360	150
WJAG	The Norfolk Daily News..	Norfolk, Nebr......	1060	283	250
WJAK	Clifford L. White.........	Greentown, Ind.....	1180	254	30
WJAM	D. M. Perham............	Cedar Rapids, Iowa.	1120	268	20
WJAN	Peoria Star Co............	Peoria, Ill.........	1070	280	100
WJAR	The Outlet Co............	Providence, R. I....	833	360	500
WJAS	Pittsburgh Radio Sup. Hse.	Pittsburgh, Pa......	1050	286	500
WJAX	Union Trust Co...........	Cleveland, Ohio....	770	390	500
WJAZ	Chicago Radio Lab........	Chicago, Ill. (Port.).	1120	268	100
WJD	Denison Univ.............	Granville, Ohio.....	1310	229	10
WJJD	Sup. Lodge Loy. Ord. Moose	Mooseheart, Ill.....	1080	278	500
WJY	Radio Corp. of America....	New York, N.Y....	740	405	750
WJZ	Radio Corp. of America....	New York, N.Y....	660	454	500
WKAA	H. F. Parr...............	Cedar Rapids, Iowa.	1080	278	50
WKAD	Charles Looff............	East Providence, R.I.	1250	240	20
WKAF	W. S. Radio Supply Co....	Wichita Falls, Tex..	833	360	100
WKAN	United Battery Serv. Co...	Montgomery, Ala...	1330	225	20
WKAP	Dutee W. Flint...........	Cranston, R. I......	833	360	50
WKAQ	Radio Corp. of P. R.......	San Juan, Porto Rico	833	360	500
WKAR	Mich. Agri. College.......	East Lansing, Mich.	1070	280	500
WKAV	The Laconia Radio Club..	Laconia, N. H......	1180	254	50
WKAY	Brenau College...........	Gainseville, Ga.....	1070	280	10
WKBF	Dutee Wilcox Flint.......	Cranston, R. I......	1050	286	500
WKY	WKY Radio Shop.........	OklahomaCity, Okla.	833	360	100
WLAH	Samuel Woodworth.......	Syracuse, N.Y......	1280	234	100
WLAL	Naylor Elec. Co..........	Tulsa, Okla........	833	360	100
WLAP	W. V. Jordan............	Louisville, Ky......	1050	286	20
WLAX	Greencastle Community Broadcasting Station....	Greencastle, Ind....	1300	231	10
WLBL	WisconsinDept. of Markets	Stevens Point, Wis..	1080	278	500
WLS	Sears, Roebuck & Co......	Chicago, Ill........	870	345	500
WLW	Crosley Radio Corp.......	Cincinnati, Ohio....	710	423	500
WMAC	Clive B. Meredith........	Cazenovia, N.Y.....	1150	261	100
WMAF	Round Hills Radio Corp...	S.Dartmouth, Mass.	833	360	500
WMAH	General Supply Co........	Lincoln, Nebr......	1180	254	100
WMAK	Lockport Brd. of Commerce	Lockport, N.Y......	1100	273	500
WMAN	First Baptist Church......	Columbus, Ohio....	1050	286	50
WMAQ	Chicago Daily News......	Chicago, Ill........	670	448	500
WMAV	Alabama Polytechnic Inst.	Auburn, Ala........	1200	250	500
WMAY	Kingshighway Presby. Ch.	St. Louis, Mo......	1070	280	100
WMAZ	Mercer University........	Macon, Ga.........	1150	261	100
WMC	The Commercial Pub. Co..	Memphis, Tenn.....	600	500	500
WMU	Doubleday-Hill Elec. Co..	Washington, D.C....	1150	261	100

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WNAC	Shepard Stores...........	Boston, Mass.......	1080	278	100
WNAD	Univ. of Oklahoma.........	Norman, Okla......	1180	254	100
WNAL	Omaha Central High School	Omaha, Nebr.......	1160	259	20
WNAP	Wittenberg College........	Springfield, Ohio...	1090	275	100
WNAR	First Christian Church....	Butler, Mo.........	1300	231	20
WNAT	Lenning Bros. Co..........	Philadelphia, Pa....	833	360	100
WNAW	Henry Kunzman..........	Fort Monroe, Va....	833	360	10
WNAX	Dakota Radio App. Co....	Yankton, S. D......	1230	244	100
WNYC	Dept.ofPlant and Structure	New York, N.Y....	570	526	1000
WOAC	Pagan Organ Co..........	Lima, Ohio.........	1130	265	150
WOAE	Midland College..........	Fremont, Nebr.....	1070	280	15
WOAF	Tyler Commercial College.	Tyler, Texas.......	833	360	20
WOAI	Southern Equip. Co.......	San Antonio, Tex...	780	384	500
WOAN	James D. Vaughan.......	Lawrenceburg,Tenn.	833	360	200
WOAR	Henry P. Lundskow......	Kenosha, Wis......	1310	229	50
WOAV	Pennsylvania Nat. Guard..	Erie, Pa...........	1240	242	50
WOAW	Sovereign Camp, Woodmen of the World...........	Omaha, Nebr.......	570	526	500
WOAX	Franklyn J. Wolff.........	Trenton, N. J......	1250	240	500
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa...	620	484	500
WOI	Iowa State College........	Ames, Iowa........	833	360	500
WOO	John Wanamaker.........	Philadelphia, Pa....	590	508	500
WOQ	Western Radio Co........	Kansas Citv, Mo...	833	360	500
WOR	L. Bamberger & Co.......	Newark, N. J.......	740	405	500
WOS	Mo. State Marketing Bur..	Jefferson City, Mo..	680	441	500
WPAB	Pennsylvania State College	State College, Pa....	1060	283	500
WPAC	Donaldson Radio Co......	Okmulgee, Okla.....	833	360	100
WPAJ	Doolittle Radio Corp......	New Haven, Conn...	1120	268	100
WPAK	Agri. College of N. Dakota	Fargo, N. Dakota..	1060	283	50
WPAL	Avery & Loeb Elec. Co....	Columbus, Ohio....	1050	286	500
WPAM	Auerbach & Geuttel......	Topeka, Kans......	1090	275	100
WPAR	Ward Battery & Radio Co.	Beloit, Kansas.....	1270	236	10
WPAU	Concordia College........	Moorhead, Minn....	1050	286	10
WPAZ	Dr. John R. Koch........	Charleston, W. Va..	1100	273	10
WQAA	Horace A. Beale, Jr.......	Parkesburg, Pa.....	833	360	500
WQAC	Gish Radio Service.......	Amarillo, Tex......	1280	234	100
WQAE	Moore Radio News Station	Springfield, Vt......	1090	275	50
WQAF	Sandusky Register........	Sandusky, Ohio.....	1250	240	5
WQAM	Electrical Equip. Co.......	Miami, Fla.........	1060	283	100
WQAN	Scranton Times..........	Scranton, Pa........	1070	280	100
WQAO	Calvary Baptist Church...	New York, N.Y....	833	360	100
WQAQ	Abilene Daily Reporter (West Texas Radio Co.).	Abilene, Tex.......	833	360	50
WQAS	Prince-Walter Co.........	Lowell, Mass.......	1130	265	100
WQAX	Radio Equip. Co..........	Peoria, Ill..........	1210	248	100
WQJ	Calumet Baking PowderCo.	Chicago, Ill........	670	448	500
WRAF	Radio Club, Inc..........	Laporte, Ind.......	1340	224	10
WRAL	Northern States Power Co.	St. Croix Falls, Wis.	1210	248	10
WRAM	Lombard College.........	Galesburg, Ill......	1230	244	100
WRAN	Black Hawk Elec. Co......	Waterloo, Iowa.....	1270	236	10
WRAO	St. Louis Radio Service Co.	St. Louis, Mo......	833	360	10
WRAV	Antioch College..........	Yellow Springs, O..	1240	242	100
WRAW	Avenue Radio&Elec. Shop.	Reading, Pa........	1260	238	10
WRAX	Flexon's Garage..........	Gloucester City,N.J.	1120	268	100
WRBC	ImmanuelLutheran Church	Valparaiso, Ind.....	1080	278	500
WRC	Radio Corp. of America...	Washington, D. C..	640	469	500
WRK	Doron Bros. Elec. Co.....	Hamilton, Ohio....	833	360	200
WRL	Union College............	Schenectady, N.Y..	833	360	500
WRM	Univ. of Illinois.........	Urbana, Ill.........	833	360	500
WRR	City of Dallas, Police and Fire Signal Dept........	Dallas, Texas......	833	360	30
WRW	Tarrytown Radio Research	Tarrytown, N.Y....	1100	273	500
WSAC	Clemson Agri. College.....	ClemsonCollegeS.C.	833	360	500
WSAD	J. A. Foster Co...........	Providence, R.I....	1150	261	100

Active Broadcasting Stations, October 24, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WSAI	U. S. Playing Card Co.....	Cincinnati, Ohio....	970	309	500
WSAJ	Grove City College........	Grove City, Pa.....	1160	259	250
WSAP	Seventh Day Adventist Church................	New York, N.Y....	1140	263	250
WSAR	Doughty & Welch Elec. Co.	Fall River, Mass....	1180	254	10
WSAU	Camp Marienfeld.........	Chesham, N. H.....	1310	229	10
WSAV	Clifford W. Vick Radio Constr. Co.............	Houston, Tex.......	833	360	100
WSAX	Chicago Radio Lab........	Chicago, Ill.........	1120	268	20
WSAZ	Chase Electric Shop.......	Pomeroy, Ohio.....	1160	259	50
WSB	Atlanta Journal..........	Atlanta, Ga........	700	428	500
WSL	J. & M. Electric Co.......	Utica, N. Y........	1100	273	10
WSOE	School of Eng. of Milwaukee	Milwaukee, Wis.....	1220	246	100
WSY	Alabama Power Co........	Birmingham, Ala....	833	360	500
WTAB	Fall River Daily Herald Co.	Fall River, Mass....	1130	265	100
WTAC	Penn Traffic Co...........	Johnstown, Pa......	1090	275	150
WTAF	Louis J. Gallo............	New Orleans, La....	1120	268	10
WTAJ	The Radio Shop..........	Portland, Maine....	1270	236	10
WTAL	Toledo Radio & Elec. Co..	Toledo, Ohio.......	1190	252	10
WTAM	The Willard Stor.Batt.Co.	Cleveland, Ohio....	770	389	1000
WTAP	Cambridge Radio&Elec.Co.	Cambridge, Ill......	1240	242	50
WTAQ	S. H. Van Gorden & Son..	Osseo, Wis.........	1180	254	100
WTAR	Reliance Elec. Co.........	Norfolk, Va........	1070	280	100
WTAS	Chas E. Erbstein.........	Elgin, Ill..	1050	286	500
WTAT	The Edison Elec. Illuminating Co of Boston. ...	Boston, Mass. (Portable).......	1220	246	100
WTAU	Ruegy Battery & Elec. Co.	Tecumseh, Nebr....	1240	242	10
WTAW	Agri. & Mech. Col. of Tex.	College Station, Tex.	1070	280	250
WTAX	Williams Hardware Co....	Streator, Ill........	1300	231	50
WTAY	Oak Leaves Broadcasting Station (Pioneer Pub.Co.)	Oak Park, Ill.......	1060	283	500
WTAZ	Thomas J. McGuire.......	Lambertville, N. J..	1060	283	15
WTG	Kansas State Agri. College	Manhattan, Kans...	1100	273	50
WWAD	Wright & Wright, Inc.....	Philadelphia, Pa....	833	360	500
WWAE	The Alamo Ball Room....	Joliet, Ill...........	1240	242	500
WWAO	Michigan College of Mines.	Houghton, Mich....	1230	244	250
WWI	Ford Motor Co...........	Dearborn, Mich....	1100	273	250
WWJ	Evening News Ass'n......	Detroit, Mich......	580	517	500
WWL	Loyola University........	New Orleans, La....	1120	268	5

MEXICAN BROADCASTING STATIONS

CYB	El Buen Tono............	S.A.Mex.City,Mex..	681	440	50
CYL	La Casa del Radio.........	Mexico City, Mex...	600	500	500
8CYR	Rosetter y Cia...........	Mazatlan, Sinaloa, Mexico..........	681	440	50

AUSTRALIAN BROADCASTING STATIONS

2BS	Broadcasters Sydney, Ltd.	Sydney, N.S.W.....	857	350	500
2FC	Farmers & Co............	Sydney, N.S.W.....	273	100	5000
2FL	Farmers & Co............	Sydney, N.S.W.....	389	770	500
3AR	Associated Radio Co. of Aust.	Melbourne, Victoria.	625	480	1600
3JO	Broadc'g Co. of Australia..	Melbourne, Victoria.	750	400	500
3LO	Broadc'g Co. of Australia..	Melbourne, Victoria.	174	1720	5000
3MA	Millswood Auto & Radio Co.	Adelaide, S. Australia	353	480	3000
6AR	Associated Radio Co......	Perth, S. Australia..	833	360	1600
6WF	Westralian Farmers, Ltd.	Perth, W. Australia.	240	1250	5000

Active Broadcasting Stations, October 24, 1924

CANADIAN BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	The Calgary Herald.......	Calgary, Alberta...	697	430	500
CFCA	Star Pub. & Print. Co.....	Toronto, Ontario...	750	400	1000
CFCF	Marconi Wireless Telegraph Co. of Canada..........	Montreal, Quebec...	681	440	500
CFCH	Abitibi Power & Paper Col.	Iroquois Falls Ont..	750	400	250
CFCK	Radio Supply Co., Ltd....	Edmonton, Alberta.	731	410	50
CFCL	Centennial Me. Church...	Victoria, B. C......	750	400	125
CFCN	W. W. Grant Radio, Ltd...	Calgary, Alberta...	681	440	1000
CFCQ	Radio Specialties, Ltd.....	Vancouver, B.C.....	666	450	5
CFCR	Laurentide Air Service,Ltd.	Sudbury, Ont.......	731	410	50
CFCT	Victoria City Temple.....	Victoria, B.C.......	731	410	250
CFCU	Jack V. Elliot, Ltd........	Hamilton, Ont......	731	410	5
CFCW	London Radio Company...	London, Ont........	697	430	150
CFDC	Sparks Company..........	Nanaimo, B.C......	697	430	50
CFHC	Henry Birks & Sons, Ltd..	Calgary, Alberta....	681	440	1000
CFKC	D. J. Fendell.............	Thorold, Ontario...	1016	295	75
CFLC	Chas. Guy Hunter.........	London, Ontario....	697	430	50
CFQC	The Electric Shop, Ltd....	Saskatoon, Sask....	750	400	50
CFRC	Queens University.........	Kingston, Ont......	666	450	500
CFXC	Westminster Trust Co.....	NewWestmin's, B.C.	681	440	20
CFCY	Victor Wentworth Odlum..	Vancouver, B.C.....	750	400	5
CHBC	The Albertan Pub. Co.....	Calgary, Alberta....	731	410	125
CHCE	Western Can. Radio Supply	Victoria, B.C.......	750	400	5
CHCM	Riley & McCormick, Ltd..	Calgary, Alberta...	681	440	1000
CHCS	The Hamilton Spectator...	Hamilton, Ont......	731	410	125
CHNC	TorontoRadioResearchSoc.	Toronto, Ontario...	857	350	50
CHUC	InternationalBibleStudents Association............	Saskatoon, Sask....	750	400	50
CHXC	J. R. Booth, Jr...........	Ottawa, Ontario....	690	435	250
CHYC	Northern Elec. Co., Ltd...	Montreal, Quebec...	880	341	500
CJBC	Jarvis St. Baptist Church..	Toronto, Ontario...	961	312	1000
CJCA	The EdmontonJournal,Ltd.	Edmonton, Alberta.	666	450	125
CJCD	T. Eaton Co., Ltd.........	Toronto, Ontario...	731	410	50
CJCE	Sprott-Shaw Radio Co.....	Vancouver, B.C.....	750	400	50
CJCF	The News Record.........	Kitchener, Ontario..	1016	295	100
CJCK	Rad. Corp. of Calgary, Ltd.	Calgary, Alberta...	950	316	250
CJCM	J. L. Phillipe Landry......	Monti Joli, Quebec.	961	312	500
CJN	Simons, Agnew & Co.......	Toronto, Ontario...	731	410	1000
CJGC	London Free Press Printing Co., Ltd............	London, Ontario....	697	430	50
CJSC	The Evening Telegram.....	Toronto, Ontario...	697	430	125
CKAC	La Presse Pub. Co.. Ltd...	Montreal, Quebec...	692	425	500
CKCD	Vancouver Daily Province.	Vancouver, B.C.....	731	410	500
CKCE	Canadian Independent Telephone Co..........	Toronto, Ontario...	666	450	1000
CKCI	Le "Soleil" Limitee........	Quebec, P.Q........	1016	295	50
CKCK	Leader Pub. Co., Ltd......	Regina, Sask.......	714	420	1000
CKCO	Dr. G. M. Geldert (for Ottawan Radio Ass'n)...	Ottawa, Ont.......	750	400	50
CKCX	P. Burns & Co., Ltd.......	Calgary, Alberta...	681	440	1000
CKFC	FirstCongregationalChurch	Vancouver, B.C.....	779	385	50
CKLC	Wilkinson Electric Co.....	Calgary, Alberta...	750	400	50
CKOC	Wentworth Radio Supply Co., Ltd...............	Hamilton, Ontario..	731	410	50
CKY	Manitoba Tel. System....	Winnipeg, Manitoba	666	450	500
CNRC	Canad. National Railways	Calgary, Alberta .	681	440	1000
CNRE	" " "	Edmonton, Alberta.	666	450	125
CNRM	" " "	Montreal, Quebec...	880	341	500
CNRO	" " "	Ottawa, Ontario ...	690	435	500
CNRR	" " "	Regina, Sask.......	714	420	1000
CNRS	" " "	Saskatoon, Sask....	750	400	50
CNRT	" " "	Toronto, Ontario...	750	400	1000
CNRW	" " "	Winnipeg, Man.....	666	450	500

BRITISH BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
2BD	17 Belmont St., Aberdeen..	Aberdeen Steam Laundry.........	605	495	1500
6BM	72 Holdenhurst Road, Bournemouth..........	Bushey Road, North Cemetery........	778	385	1500
5IT	105 New Street, Birmingham..................	Summer Lane Power Station........	631	475	1000
2LO	2 Savoy Hill, Victoria Embankment, London......	Marconia House, Strand..........	821	365	1500
5NO	24 Eldon Sq., Newcastle...	CWS Bldg., Blandford Street.......	750	400	1500
5SC	202 Bath Street, Glasgow..	Port Dundas.......	714	420	1500
5WA	19 Castle Street, Cardiff...	Eldon Rd. Generating Station......	857	350	1500
2ZY	57 Dickinson Street......	Manchester........	789	375	1500
6SL	Union Grinding Wheel, Sheffield...............	Corporation Street	989	303	100

CUBAN BROADCASTING STATIONS

PWX	Cuban Telephone Co......	Havana...........	750	400	500
2AB	Alberto S. Bustamante....	"	1249	240	20
2BY	Frederick W. Borton......	"	1153	260	100
2CX	Frederick W. Borton......	"	937	320	10
2DW	Pedro Zayas.............	"	999	300	100
2EV	Westinghouse Electric Co..	"	1363	220	50
2HS	Julio Power.............	"	1666	180	20
2JQ	Raul Perez Falcon.........	"	1999	150	10
2KD	E. Sanchez de Fuentes....	"	857	350	100
2KP	Alvaro Daza.............	"	1499	200	10
2LC	Luis Casas.............	"	1199	250	30
2MG	Manuel G. Salas.........	"	1071	280	20
2OK	Mario Garcia Velez.......	"	833	360	100
2OL	Oscar Collado...........	"	1034	290	15
2TW	Roberto E. Ramirez......	"	1304	230	20
2WW	Amadeo Saenz...........	"	1428	210	20
5EV	Leopoldo V. Figueroa.....	Colon.............	833	360	100
6AZ	Valenten Ullivarri........	Cienfuegos.........	1499	200	10
6BY	Jose Ganduxe............	"	999	300	100
6CX	Antonio T. Figueroa......	"	1764	170	20
6DW	Eduardo Terry...........	"	1330	225	10
6EV	Josefa Alvarez...........	Caibarien..........	1330	225	20
6GT	Juan Pablo Ros..........	Cienfuegos.........	1578	190	10
6KJ	Frank H. Jones..........	Tuinicu...........	1090	275	100
6KW	Frank H. Jones..........	"	882	340	100
7AZ	Pedro Nogueras..........	Camaguey.........	1330	225	10
7BY	Eduardo V. Figueroa......	C. De Avila........	1275	235	20
7SR	Salvador Rionda.........	C. Elia...........	857	350	500
8AZ	Afredo Broocks..........	Santiago de Cuba ..	1249	240	20
8BY	Alberto Ravelo..........	" " " ..	1199	250	100
8DW	Pedro C. Andux..........	" " " ..	1666	180	75
8EV	Eduardo Mateos.........	" " " ..	1330	225	15
8FU	Andres Vinnet..........	" " " ..	1330	225	15
8GT	Juan E. Chibas..........	" " " ..	1153	260	50

ARGENTINE BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
LOR	Radio Argentina..........	Buenos Aires.......	750	400	1500
LOV	F. Brusa...............	Buenos Aires.......	857	350	500
LOW	Grand Splendid.........	Buenos Aires.......	923	325	1000
LOX	Radio Cultura...........	Buenos Aires.......	800	375	500
LOY	Radio Nacional..........	Buenos Aires.......	923	325	1000
LOZ	Radio South America.....	Monte Grande.....	706	425	500

GEOGRAPHICAL LIST OF BROADCASTING STATIONS

October 24, 1924

(See Alphabetical List for details)

Alabama
Auburn........WMAV
Birmingham...WSY
Mobile........WEAP
Montgomery...WKAN

Alaska
Anchorage.....KFQD
Juneau........KFIU
Kukak Bay....KNT

Arizona
Phoenix.......KFAD
KFCB
Tucson........KFDH

Arkansas
Conway.......KFKQ
KFRJ
Fayetteville....KFMQ
Fort Smith....KFOZ
Little Rock....KFLQ
KFMB
WCAV
Pine Bluff.....KFPX

California
Bakersfield....KDZB
Berkeley......KRE
Burlingame....KFNZ
KFQH
Culver City....KFQI
El Monte......KUY
Fresno........KMJ
Hollywood.....KFAR
KFQZ
Holy City.....KFQU
Long Beach....KFON
Los Angeles....KFCL
KFI
KFPG
KFPR
KFQG
KFSG
KHJ
KJS
KNX
KWH
Oakland.......KGO
KLS
KLX
KZM
Paso Robles....KFNL
Richmond.....KFOU
Sacramento....KFBK
San Diego.....KDPT
KDYM
KFBC
San Francisco..KFPV
KFRC
KPO
KUO
San Jose.......KQW
San LuisObispo.KFBE
Santa Ana.....KFAW
Santa Barbara..KFHJ
Santa Rosa....KFNV
Stanford Univ..KFGH
Stockton.......KJQ
KWG
Taft..........KFQC
Whittier.......KFOC

Colorado
Boulder.......KFAJ
Colorado Sprgs.KFKZ
KFQE
Denver........KFAF
KFDL
KFEL
KFLE
KFPO
KFRI
KLZ
Greeley........KFKA
Gunnison......KFHA
Manitou.......KFQS
Trinidad.......KFBS

Connecticut
New Haven....WPAJ
Storrs.........WABL

Delaware
Wilmington....WHAV

District of Columbia
Washington....WABE
WCAP
WDM
WMU
WRC

Florida
DeLand.......WEBU
Miami........WQAM
Pensacola......WGAN
St Petersburg..WCBK
WDBI
Tampa........WDAE
Winter Park...WDBO

Georgia
Atlanta........WBBF
WSB
Gainesville.....WKAY
Macon........WCBW
WMAZ
Savannah......WEBZ

Hawaii
Honolulu......KGU
KYQ

Idaho
Boise..........KFDD
KFFB
Moscow.......KFAN
Wallace.......KFOD

Illinois
Cambridge.....WTAP
Chicago.......KYW
WAAF
WDBY
WEBH
WGN
WJAZ
WLS
WMAQ
WQJ
WSAX
Chicago HeightsWCBZ
Decatur.......WBAO
Elgin..........WTAS
Eureka........WFBB
Galesburg.....WRAM
Harrisburg.....WEBQ
Joliet..........WWAE
Monmouth....WBBU
Mooseheart....WJJD
Oak Park......WTAY
Peoria.........WJAN
WQAX
Rockford......KFLV
WIAB
Streator.......WTAX
Tuscola.......WDZ
Urbana........WRM
Zion...........WCBD

Indiana
Anderson......WEBD
Greencastle....WLAX
Greentown.....WJAK
Indianapolis...WBBZ
WFBM
Laporte.......WRAF
South Bend....WGAZ
Valparaiso.....WRBC
West Lafayette.WBAA

Iowa
Ames..........WOI
Atlantic.......KFLZ
Boone.........KFGQ
Burlington.....WIAS
Cedar Falls....KFJX
Cedar Rapids..WJAM
WKAA
Davenport.....WOC
Des Moines....WHO
Fort Dodge....KFER
KFJY
Iowa City.....KFQP
WHAA
Lamoni........KFFV
Marengo.......KFOL
Marshalltown..KFJB
Shenandoah....KFNF
Sioux City.....KFMR
WEAU
Waterloo......WRAN

Kansas
Anthony.......WBL
Beloit.........WPAR
Manhattan....WTG
Milford........KFKB
Russell........KFQO
WPAM
Wichita.......KFOT
WEAH

Kentucky
Louisville......WHAS
WLAP

Louisiana
Alexandria.....KFFY
KFRF
Baton Rouge...KFGC
Jennings.......WCBJ
New Orleans...WAAB
WAAC
WABZ

Geographical List of Broadcasting Stations, October 24, 1924
(See Alphabetical List for details)

New Orleans	WCAG
	WCBE
	WEBP
	WEBS
	WTAF
	WWL
Shreveport	KFDX
	WGAQ
Maine	
Bangor	WABI
Houlton	WCBL
Portland	WTAJ
Skowhegan	WDBU
Maryland	
Baltimore	WCAO
	WEAR
Salisbury	WEBI
Massachusetts	
Boston	WDBR
	WEEI
	WNAC
	WTAT
Bridgewater	WFBN
Fall River	WSAR
	WTAB
Lowell	WQAS
Mattapoisett	WBBG
Medford Hillside	WGI
New Bedford	WDAU
Roslindale	WEBY
S. Dartmouth	WMAF
Springfield	WBZ
Taunton	WDBB
Worcester	WCBT
	WDAS
	WDBH
Michigan	
Ann Arbor	WCBC
Berrien Springs	KFGZ
Dearborn	WWI
Detroit	KOP
	WCX
	WWJ
East Lansing	WKAR
Flint	WEAA
Grand Rapids	WEBK
Houghton	KFMW
	WWAO
Menominee	KFLB
Mt. Clemens	WABX
Petoskey	WBBP
Port Huron	WBBH
Saginaw	WABM
Minnesota	
Collegeville	WFBJ
Hutchinson	WFAN
Minneapolis	KFDZ
	KFEX
	KFMT
	KFQF
	WCAS
	WCCO
Moorhead	WPAU
Northfield	KFMX
	WCAL
St. Cloud	WFAM
St. Paul	KFOY
Mississippi	
Coldwater	KFNG
Hattiesburg	WDBT
Oxford	WCBH
Pascagoula	WCBG
Missouri	
Butler	WNAR
Carterville	KFPW
Columbia	WAAN
Fayette	KFQK
Independence	KFIX
Jefferson City	KFPN
	WOS
Kansas City	WDAF
	WHB
	WOQ
Moberly	KFFP
	KFOJ
St. Joseph	KFHD
St. Louis	KFQA
	KFRG
	KSD
	WCK
	WEB
	WEW
	WMAY
	WRAO
Montana	
Butte	KFKV
	KFLA
Havre	KFBB
Helena	KFNY
	KFSY
Missoula	KFLW
Stevensville	KFJR
Nebraska	
Belden	KFQY
David City	KFOR
Fremont	WOAE
Hastings	KFKX
Lincoln	WFAV
	WJAB
	WMAH
Norfolk	WJAG
Oak	KFEQ
Omaha	KFCZ
	KFOX
	KFQV
	WAAW
	WIAK
	WNAL
	WOAW
Tecumseh	WTAU
Univ. Place	WCAJ
Nevada	
Sparks	KFFR
New Hampshire	
Chesham	WSAU
Hanover	WFBK
Laconia	WKAV
New Jersey	
Atlantic City	WHAR
Camden	WABU
	WFBI
Gloucester City	WRAX
Highland Park	WEBA
Lambertville	WTAZ
Newark	WAAM
	WBS
	WCBX
	WOR
North Plainfield	WEAM
Paterson	WBAN
Salem	WDBQ
	WOAX
New Mexico	
Albuquerque	KFLR
State College	KOB
New York	
Buffalo	WEBR
	WGR
Canton	WCAD
Cazenovia	WMAC
Ithaca	WEAI
Kingston	WDBZ
Lockport	WMAK
New York City	WBAY
	WDBX
	WEAF
	WEBJ
	WEBL
	WFBH
	WGBS
	WHN
	WJY
	WJZ
	WNYC
	WQAO
	WSAP
Richmond Hill	WAHG
Rochester	WABO
	WHAM
Rossville	WBBR
Schenectady	WGY
	WRL
Syracuse	WFAB
	WFBL
	WLAH
Tarrytown	WRW
Troy	WHAZ
Utica	WSL
North Carolina	
Charlotte	WBT
North Dakota	
Fargo	WDAY
	WPAK
Grafton	KFRH
Grand Forks	KFJM
	KFJQ
Ohio	
Cambridge	WEBE
Cincinnati	WAAD
	WFBW
	WHAG
	WLW
	WSAI
Cleveland	KDPM
	WHK
	WJAX
	WTAM
Columbus	WBAV
	WCAH
	WEAO
	WMAN

Geographical List of Broadcasting Stations, October 24, 1924
(See Alphabetical List for details)

Columbus..... WPAL
Dayton........ WARD
WDBS
WEBT
Dover......... WABP
Granville...... WJD
Hamilton...... WEBO
WRK
Lima.......... WOAC
Newark........ WBBA
Pomeroy...... WSAZ
Sandusky...... WABH
WQAF
Springfield..... WNAP
Toledo........ WABR
WTAL
Wooster....... WABW
Yellow Springs. WRAV
Youngstown... WDBF

Oklahoma

Bristow........ KFJK
Chickasha..... KFGD
Muskogee..... KFQL
Norman....... WNAD
Oklahoma City. KFJF
KFQJ
KFQR
WKY
Okmulgee...... WPAC
Tulsa......... WLAL

Oregon

Arlington...... KFGL
Astoria......... KFJI
Corvallis...... KFDJ
Hood River.... KQP
Marshfield..... KFOF
Medford....... KFAY
Pendleton..... KFFE
Portland....... KDYQ
KFEC
KFIF
KFQN
KGG
KGW

Pennsylvania

Allentown..... WCBA
Altoona....... WFBG
Arnold........ WCBU
Buck Hill Falls. WCBY
Butler......... WBR
EastPittsburgh. KDKA
Erie.......... WOAV
Grove City.... WSAJ
Harrisburg..... WABB
WBAK
Haverford..... WABQ
Johnstown..... WBBV
WTAC
Lancaster...... WDBC
WGAL
McKeesport... WIK
Parkesburg.... WQAA
Philadelphia... WABY
WBBT
WCAU
WDAR
WFI
WGL
WIAD
WIP
WNAT
WOO
WWAD
Pittsburgh..... KQV
WCAE
WJAS
Reading....... WBBD
WRAW
Scranton...... WQAN
State College... WPAB
Wilkes-Barre... WBAX

Porto Rico

San Juan...... WKAQ

Rhode Island

Cranston...... WKAP
WKBF
Providence..... WCBR
WEAN
WJAR
WKAD
WSAD

South Carolina

Charleston..... WBBY
Clemson College WSAC

South Dakota

Brookings..... KFDY
Rapid City.... WCAT
Vermillion..... WEAJ
Yankton...... WNAX

Tennessee

Bemis......... WCBI
Columbia...... WDBW
Lawrenceburg.. WOAN
Memphis...... WCBO
WMC
Nashville...... WCBQ
WEBX
Tullahoma..... WCBV

Texas

Abilene........ WQAQ
Amarillo....... WDAG
WQAC
Austin........ KFQM
Beeville....... KFRB
College Station. WTAW
Dallas......... WFAA
WRR
Denison....... KFQT
Dublin........ KFPL
El Paso....... WDAH
Fort Worth.... KFJZ
KFQB
WBAP
Galveston..... KFLX
KFOQ
WIAC
Greenville..... KFPM
Houston....... KFCV
WCAK
WEAY
WEV
WSAV
Orange......... KFGX
San Antonio... WCAR
WOAI
San Benito..... KFLU
Tyler.......... WOAF
Waco......... WJAD
Wichita Falls.. WKAF

Utah

Ogden........ KFCP
Salt Lake City. KDYL
KFOO
KFPH
KFPT

Vermont

Burlington..... WCAX
Springfield..... WQAE

Virginia

Fort Monroe... WNAW
Norfolk....... WBBW
WTAR
Richmond..... WBBL
Roanoke....... WDBJ

Washington

Bellingham.... KDZR
Everett........ KFBL
Lacey......... KGY
North Bend.... KFQW
Olympia....... KFPP
Pullman....... KFAE
Seattle........ KDZE
KFHR
KFJC
KFOA
KFQX
KHQ
KJR
KTW
Spokane....... KFIO
KFPY
Tacoma....... KFBG
KGB
KMO
Walla Wallla... KFCF
Yakima....... KFIQ

West Virginia

Charleston..... WPAZ
Clarksburg.... WHAK
Martinsburg... WDBD

Wisconsin

Beloit......... WEBW
Fond du Lac... KFIZ
Kenosha....... WOAR
La Crosse..... WABN
Madison....... WHA
Milwaukee..... WCAY
WHAD
WSOE
Osseo......... WTAQ
St. Croix Falls.. WRAL
Stevens Point.. WDBL
WLBL
Superior....... WDBP
WEBC

Wyoming

Laramie....... KFBU

Geographical List of Broadcasting Stations, October 24, 1924
(See Alphabetical List for details)

Alberta	
Calgary	CFAC
	CFCN
	CFHC
	CHBC
	CHCM
	CJCK
	CKCX
	CKLC
	CNRC
Edmonton	CFCK
	CJCA
	CNRE
British Columbia	
Nanaimo	CFDC
N. Westminster	CFXC
Vancouver	CFCQ
	CFCY
	CJCE
	CKCD
	CKFC
Victoria	CFCL
	CFCT
	CHCE
Manitoba	
Winnipeg	CKY
	CNRW
Ontario	
Hamilton	CFCU
	CHCS
	CKOC
Iroquois Falls	CFCH
Kingston	CFRC
Kitchener	CJCF
London	CFCW
	CFLC
	CJGC
Ottawa	CHXC
	CKCO
	CNRO
Sudbury	CFCR
Thorold	CFKC
Toronto	CFCA
	CHNC
	CJBC
	CJCD
	CJCN
	CJSC
	CKCE
	CNRT
Quebec	
Monti Joli	CJCM
Montreal	CFCF
	CHYC
	CKAC
	CNRM
Quebec	CKCI
Saskatchewan	
Saskatoon	CFQC
	CHUC
	CNRS
Regina	CKCK
	CNRR

QUARTERLY SERVICE

For those whose interest in Radiofax is limited to the data on broadcasting stations we have provided a special subscription plan.

A completely revised list similar to the one in this issue will be published every three months. A charge of $1.00 is made for this quarterly service.

This offer, we believe, will give the non-technical radio enthusiast an opportunity to share with our present readers the satisfaction of having a really dependable list of broadcasting stations. The cost of the service is within reach of all.

Broadcasting Stations by Frequency

Kilocycle	Call	Meters	Location
550	KSD	545	St. Louis. Mo.
560	KYW	535	Chicago, Ill.
570	WHO	526	Des Moines, Iowa
570	WNYC	526	New York, N. Y.
570	WOAW	526	Omaha, Nebr.
580	WCX	517	Detroit, Mich.
580	WWJ	517	Detroit, Mich.
590	KLX	508	Oakland, Calif.
590	WIP	508	Philadelphia, Pa.
590	WOO	508	Philadelphia, Pa.
600	WMC	500	Memphis, Tenn.
610	KGW	492	Portland, Ore.
610	WBAY	492	New York, N. Y.
610	WEAF	492	New York, N. Y.
620	WHAA	484	Iowa City, Iowa
620	WOC	484	Davenport, Iowa
630	WBAP	476	Fort Worth, Tex.
630	WFAA	476	Dallas, Tex.
640	KFI	469	Los Angeles, Calif.
640	WCAP	469	Washington, D.C.
640	WRC	469	Washington, D.C.
650	WCAE	461	Pittsburgh, Pa.
660	KFOA	454	Seattle, Wash.
660	WJZ	454	New York, N. Y.
670	WMAQ	448	Chicago, Ill.
670	WQJ	448	Chicago, Ill.
680	WOS	441	Jefferson City, Mo.
700	WSB	428	Atlanta, Ga.
710	KPO	422	San Francisco Cal.
710	WBAV	423	Columbus, Ohio
710	WLW	423	Cincinnati, Ohio
720	WCCO	417	Minneapolis Minn
730	WDAF	411	Kansas City, Mo.
730	WHB	411	Kansas City, Mo.
740	WJY	405	New York, N. Y.
740	WOR	405	Newark, N. J.
750	WBAK	400	Harrisburg, Pa.
750	WHAS	400	Louisville, Ky.
760	KHJ	395	Los Angeles, Calif.
760	WDAR	395	Philadelphia, Pa.
760	WFI	395	Philadelphia, Pa.
770	WJAX	390	Cleveland, Ohio
770	WTAM	389	Cleveland, Ohio
780	WOAI	384	San Antonio, Tex.
790	WGY	380	Schenectady, N.Y.
790	WHAZ	380	Troy, N. Y.
810	WEBH	370	Chicago, Ill.
810	WGN	370	Chicago, Ill.
833	KDYL	360	Salt Lake C., Utah
833	KDYQ	360	Portland, Ore.
833	KFAD	360	Phoenix, Ariz.
833	KFAN	360	Moscow, Idaho
833	KFBB	360	Havre, Mont.
833	KFBG	360	Tacoma, Wash.
833	KFCF	360	Walla Walla, Wash
833	KFCP	360	Ogden, Utah
833	KFCV	360	Houston, Tex.
833	KFDJ	360	Corvallis, Ore.
833	KFDX	360	Shreveport, La.
833	KFFE	360	Pendleton, Ore.
833	KFHJ	360	Santa Barbara Cal
833	KFIF	360	Portland, Ore.
833	KGG	360	Portland, Ore.
833	KGU	360	Honolulu, Hawaii
833	KHQ	360	Seattle, Wash.
833	KJQ	360	Stockton, Calif.
833	KJS	360	Los Angeles, Calif.
833	KLS	360	Oakland, Calif.
833	KMO	360	Tacoma, Wash.
833	KOB	360	State College, N.M
833	KQP	360	Hood River, Ore.
833	KQW	360	San Jose, Calif.
833	KTW	360	Seattle, Wash.
833	KUO	360	San Francisco Cal.
833	KWG	360	Stockton, Calif.
833	KWH	360	Los Angeles, Calif.
833	KZM	360	Oakland, Calif.
833	WAAC	360	New Orleans, La.
833	WAAD	360	Cincinnati, Ohio
833	WBS	360	Newark, N. J.
833	WBT	360	Charlotte, N. C.
833	WCAL	360	Northfield, Minn.
833	WCAO	360	Baltimore, Md.
833	WCAR	360	San Antonio, Tex.
833	WCAV	360	Little Rock, Ark.
833	WCAX	360	Burlington, Vt.
833	WCK	360	St. Louis, Mo.
833	WDAE	360	Tampa, Fla.
833	WDAS	360	Worcester, Mass.
833	WDAU	360	NewBedfordMass.
833	WEAP	360	Mobile, Ala.
833	WEAY	360	Houston, Tex.
833	WFAM	360	St. Cloud, Minn.
833	WGAN	360	Pensacola, Fla.
833	WGI	360	Medford Hillside, Mass.
833	WGL	360	Philadelphia, Pa.
833	WHAV	360	Wilmington, Del.
833	WHN	360	New York, N. Y.
833	WIAC	360	Galveston, Tex.
833	WJAD	360	Waco, Tex.
833	WJAR	360	Providence, R. I.
833	WKAF	360	Wichita Falls, Tex.
833	WKAP	360	Cranston, R. I.
833	WKAQ	360	San Juan, P. R.
833	WKY	360	Oklahoma City, Okla.
833	WLAL	360	Tulsa, Okla.
833	WMAF	360	South Dartmouth, Mass.
833	WNAT	360	Philadelphia, Pa.
833	WNAW	360	Ft. Monroe, Va.
833	WOAF	360	Tyler, Tex.
833	WOAN	360	Lawrenceburg, Tenn.
833	WOI	360	Ames, Iowa
833	WOQ	360	Kansas City, Mo.
833	WPAC	360	Okmulgee, Okla.
833	WQAA	360	Parkesburg, Pa.
833	WQAO	360	New York, N. Y.
833	WQAQ	360	Abilene, Tex.
833	WRAO	360	St. Louis, Mo.
833	WRK	360	Hamilton, Ohio.
833	WRL	360	Schenectady, N.Y.
833	WRM	360	Urbana, Ill.
833	WRR	360	Dallas, Tex.
833	WSAC	360	Clemson College, S. C.
833	WSAV	360	Houston, Tex.
833	WSY	360	Birmingham, Ala.
833	WWAD	360	Philadelphia, Pa.
870	WCBD	345	Zion, Ill.
870	WLS	345	Chicago, Ill.
890	KNX	337	Los Angeles. Calif

Kilo-cycle	Call	Met-ers	Location	Kilo-cycle	Call	Met-ers	Location
890	WBZ	337	Springfield, Mass.	1070	KFJX	280	Cedar Falls, Iowa
910	KFAE	330	Pullman, Wash.	1070	KFQD	280	Anchorage, Alaska
920	KDKA	326	E. Pittsburgh, Pa.	1070	KFRC	280	San Francisco Cal.
940	WGR	319	Buffalo, N. Y.	1070	WCAD	280	Canton, N. Y.
950	WAHG	316	Richmond Hill, N. Y.	1070	WCAS	280	Minneapolis,Minn
				1070	WCBA	280	Allentown, Pa.
950	WGBS	316	New York, N. Y.	1070	WCBC	280	Ann Arbor, Mich.
960	KGO	312	Oakland, Calif.	1070	WCBL	280	Houlton, Me.
970	WFBW	309	Cincinnati, Ohio	1070	WEAA	280	Flint, Mich.
970	WSAI	309	Cincinnati, Ohio	1070	WEAH	280	Wichita, Kans.
990	WEEI	303	Boston, Mass.	1070	WEBP	280	New Orleans, La.
1020	WEAO	294	Columbus, Ohio	1070	WEBZ	280	Savannah, Ga.
1030	KFKX	291	Hastings, Nebr.	1070	WEW	280	St. Louis, Mo.
1050	KFGZ	286	Berrien Springs, Mich.	1070	WHAD	280	Milwaukee, Wis.
				1070	WJAN	280	Peoria, Ill.
1050	KFKB	286	Milford, Kans.	1070	WKAR	280	E. Lansing, Mich.
1050	KOP	286	Detroit, Mich.	1070	WKAY	280	Gainsville, Ga.
1050	WAAF	286	Chicago, Ill.	1070	WMAY	280	St. Louis, Mo.
1050	WAAW	286	Omaha, Nebr.	1070	WOAE	280	Fremont, Nebr.
1050	WBR	286	Butler, Pa.	1070	WQAN	280	Scranton, Pa.
1050	WCAH	286	Columbus, Ohio	1070	WTAR	280	Norfolk, Va.
1050	WCAU	286	Philadelphia, Pa.	1070	WTAW	280	College Sta., Tex.
1050	WEAI	286	Ithaca, N. Y.	1080	KFAF	278	Denver, Colo.
1050	WEAM	286	N. Plainfield.N.J.	1080	KFBC	278	San Diego, Calif.
1050	WFAN	286	Hutchinson,Minn.	1080	WDBL	278	Stevens P't., Wis.
1050	WFBL	286	Syracuse, N. Y.	1080	WDZ	278	Tuscola, Ill.
1050	WJAS	286	Pittsburgh, Pa.	1080	WIAK	278	Omaha, Nebr.
1050	WKBF	286	Cranston, R. I.	1080	WJJD	278	Mooseheart, Ill.
1050	WLAP	286	Louisville, Ky.	1080	WKAA	278	Cedar Rapids, Ia.
1050	WMAN	286	Columbus, Ohio	1080	WLBL	278	Stevens PointWis.
1050	WPAU	286	Moorhead, Minn.	1080	WNAC	278	Boston, Mass.
1050	WTAS	286	Elgin, Ill.	1080	WRBC	278	Valparaiso, Ind.
1060	WABD	283	Dayton, Ohio	1090	KFFY	275	Alexandria, La.
1060	WABE	283	Washington, D.C.	1090	KRE	275	Berkeley, Calif.
1060	WABL	283	Storrs, Conn.	1090	WBAO	275	Decatur, Ill.
1060	WABO	283	Rochester, N. Y.	1090	WEAU	275	Sioux City, Iowa
1060	WBAA	283	W. Lafayette,Ind.	1090	WFAV	275	Lincoln, Nebr.
1060	WBBL	283	Richmond, Va.	1090	WGAZ	275	So. Bend, Ind.
1060	WCAJ	283	University Place, Nebr.	1090	WHA	275	Madison, Wis.
				1090	WHAR	275	Atlantic City,N.J.
1060	WDBS	283	Dayton, Ohio	1090	WNAP	275	Springfield, Ohio
1060	WEAJ	283	Vermillion, S. D.	1090	WPAM	275	Topeka, Kans.
1060	WEBW	283	Beloit, Wis.	1090	WQAE	275	Springfield, Vt.
1060	WHAM	283	Rochester, N. Y.	1090	WTAC	275	Johnstown, Pa.
1060	WHK	283	Cleveland, Ohio	1100	KFDY	273	Brookings, S.Dak.
1060	WIAS	283	Burlington, Iowa	1100	KFGH	273	Stanford Un.,Cal.
1060	WJAG	283	Norfolk, Nebr.	1100	KFIZ	273	Fond duLac, Wis.
1060	WPAB	283	State College, Pa.	1100	KFJZ	273	Fort Worth, Tex.
1060	WPAK	283	Fargo, N. D.	1100	KFKA	273	Greeley, Colo.
1060	WQAM	283	Miami, Fla.	1100	KFLZ	273	Atlantic, Iowa
1060	WTAY	283	Oak Park, Ill.	1100	FKQY	273	Belden, Nebr.
1060	WTAZ	283	Lambertville, N.J.	1100	WBBR	273	Rossville, N. Y.
1060	KFAY	283	Medford, Ore.	1100	WEAN	273	Providence, R. I.
1060	KFBK	283	Sacramento, Calif.	1100	WEB	273	St. Louis, Mo.
1060	KFBU	283	Laramie, Wyo.	1100	WEBJ	273	New York, N. Y.
1060	KFKV	283	Butte, Mont.	1100	WFBH	273	New York, N. Y.
1060	KFLA	283	Butte, Mont.	1100	WMAK	273	Lockport, N. Y.
1060	KFMX	283	Northfield, Minn.	1100	WPAZ	273	Charleston, W.Va.
1060	KFPY	283	Spokane, Wash.	1100	WRW	273	Tarrytown, N.Y.
1060	KFQN	283	Portland, Ore.	1100	WSL	273	Utica, N. Y.
1060	KJR	283	Seattle, Wash.	1100	WTG	273	Manhattan, Kans.
1060	KLZ	283	Denver, Colo.	1100	WWI	273	Dearborn, Mich.
1070	KDYM	280	San Diego, Calif.	1110	KDPM	270	Cleveland, Ohio
1070	KFAR	280	Hollywood, Calif.	1110	KDZE	270	Seattle, Wash.
1070	KFAW	280	Santa Ana, Calif.	1110	KFJC	270	Seattle, Wash.
1070	KFBS	280	Trinidad, Colo.	1110	KQV	270	Pittsburgh, Pa.
1070	KFFV	280	Lamoni, Iowa	1110	KYQ	270	Honolulu, Hawaii
1070	KFJM	280	Grand Forks,N.D.	1110	WABR	270	Toledo, Ohio
1070	KFJQ	280	Grand Forks,N.D.	1110	WABX	270	Mt. Clemens,Mich

Kilo-cycle	Call	Meters	Location	Kilo-cycle	Call	Meters	Location
1110	WBBF	270	Atlanta, Ga.	1160	WDBC	259	Lancaster, Pa.
1110	WEBT	270	Dayton, Ohio	1160	WDBU	259	Skowhegan, Me.
1120	KFDH	268	Tucson, Ariz.	1160	WDBY	259	Chicago, Ill.
1120	KFEQ	268	Oak, Nebr.	1160	WEBU	259	De Land, Fla.
1120	KFLE	268	Denver, Colo.	1160	WNAL	259	Omaha, Nebr.
1120	KFPT	268	Salt Lake C. Utah	1160	WSAJ	259	Grove City, Pa.
1120	KFPW	268	Carterville, Mo.	1160	WSAZ	259	Pomeroy, Ohio
1120	KFQM	268	Austin, Texas	1170	KUY	256	El Monte, Calif.
1120	KFRH	268	Grafton, N. Dak.	1170	WDBR	256	Boston, Mass.
1120	WAAB	268	New Orleans, La.	1170	WFBK	256	Hanover, N. H.
1120	WBBY	268	Charleston, S. C.	1180	KFEL	254	Denver, Colo.
1120	WCAG	268	New Orleans, La.	1180	KFGC	254	Baton Rouge, La.
1120	WCBG	268	Pascagoula, Miss.	1180	KFLR	254	Albuquerque,N.M
1120	WCBY	268	Buck Hill Falls,Pa	1180	KFMB	254	Little Rock, Ark.
1120	WDAH	268	El Paso, Tex.	1180	KFNG	254	Coldwater, Miss.
1120	WDBD	268	Martinsburg,WVa	1180	KFOU	254	Richmond, Calif.
1120	WDBH	268	Worcester, Mass.	1180	KFQB	254	Fort Worth, Tex.
1120	WDBW	268	Columbia, Tenn.	1180	WAAN	254	Columbia, Mo.
1120	WFBM	268	Indianapolis, Ind.	1180	WABM	254	Saginaw, Mich.
1120	WJAM	268	Cedar Rapids, Ia.	1180	WBAX	254	Wilkes Barre, Pa.
1120	WJAZ	268	Chicago, Ill.	1180	WBL	254	Anthony, Kans.
1120	WPAJ	268	New Haven, Conn	1180	WCBU	254	Arnold, Pa.
1120	WRAX	268	Gloucester C.,N.J.	1180	WIAD	254	Philadelphia, Pa.
1120	WSAX	268	Chicago, Ill.	1180	WJAK	254	Greentown, Ind.
1120	WTAF	268	New Orleans, La.	1180	WKAV	254	Laconia, N. H.
1120	WWL	268	New Orleans, La.	1180	WMAH	254	Lincoln, Nebr.
1130	KFFP	265	Moberly, Mo.	1180	WNAD	254	Norman, Okla.
1130	KFMW	265	Houghton, Mich.	1180	WSAR	254	Fall River, Mass.
1130	KFNF	265	Shenandoah, Ia.	1180	WTAQ	254	Osseo, Wis.
1130	WABB	265	Harrisburg, Pa.	1190	KFDD	252	Boise, Idaho
1130	WABP	265	Dover, Ohio	1190	KFHA	252	Gunnison, Colo.
1130	WCAY	265	Milwaukee, Wis.	1190	KFIO	252	Spokane, Wash.
1130	WCBK	265	St. Petersburg,Fla	1190	KFJF	252	OklahomaC.,Okla.
1130	WOAC	265	Lima, Ohio	1190	KFJI	252	Astoria, Ore.
1130	WQAS	265	Lowell, Mass.	1190	KFPL	252	Dublin, Tex.
1130	WTAB	265	Fall River, Mass.	1190	KFQL	252	Muskogee, Okla.
1140	KFHR	263	Seattle, Wash.	1190	KFQT	252	Denison, Tex.
1140	KFMQ	263	Fayetteville,Ark.	1190	KGB	252	Tacoma, Wash.
1140	KNT	263	Kukak Bay, Ala.	1190	WCBV	252	Tullahoma, Tenn.
1140	WAAM	263	Newark, N. J.	1190	WDBN	252	Bangor, Me.
1140	WABZ	263	New Orleans, La.	1190	WEBS	252	New Orleans, La.
1140	WCAK	263	Houston, Tex.	1190	WGAQ	252	Shreveport, La.
1140	WCBE	263	New Orleans, La.	1190	WIAB	252	Rockford, Ill.
1140	WDAG	263	Amarillo, Tex.	1190	WTAL	252	Toledo, Ohio
1140	WEBX	263	Nashville, Tenn.	1200	KFGX	250	Orange, Tex.
1140	WEV	263	Houston, Tex.	1200	KFKQ	250	Conway, Ark.
1140	WSAP	263	New York, N. Y.	1200	KFQR	250	Oklahoma C.Okla.
1150	KDZR	261	Bellingham, Wash	1200	KFRJ	250	Conway, Ark.
1150	KFAJ	261	Boulder, Colo.	1200	WCBO	250	Memphis, Tenn.
1150	KFEX	261	MinneapolisMinn.	1200	WEBO	250	Hamilton, Ohio
1150	KFLQ	261	Little Rock, Ark.	1200	WMAV	250	Auburn, Ala.
1150	KFMR	261	Sioux City, Ia.	1210	KFEC	248	Portland, Ore.
1150	KFNY	261	Helena, Mont.	1210	KFGD	248	Chicakasha, Okla.
1150	KFOO	261	Salt Lake C. Utah	1210	KFJB	248	Marshalltown, Ia.
1150	KFQA	261	St. Louis, Mo.	1210	KFLB	248	Menominee, Mich.
1150	KFQO	261	Russell, Kans.	1210	KFOX	248	Omaha, Nebr.
1150	KFSY	261	Helena, Mont.	1210	KFQW	248	No. Bend, Wash.
1150	WABQ	261	Haverford, Pa.	1210	KFRB	248	Beeville, Tex.
1150	WDBP	261	Superior, Wis.	1210	KMJ	248	Fresno, Calif.
1150	WEAR	261	Baltimore, Md.	1210	WBBG	248	Mattapoisett, Mass.
1150	WEBK	261	Grd.Rapids, Mich				
1150	WFBG	261	Altoona, Pa.	1210	WBBV	248	Johnstown, Pa.
1150	WMAC	261	Cazenovia, N.Y.	1210	WCBZ	248	Chicago Hgts.,Ill.
1150	WMAZ	261	Macon, Ga.	1210	WEBE	248	Cambridge, Ohio
1150	WMU	261	Washington, D.C.	1210	WGAL	248	Lancaster, Pa.
1150	WSAD	261	Providence, R. I.	1210	WRAL	248	St.CroixFalls,Wis.
1160	KFCZ	259	Omaha, Nebr.	1210	WQAX	248	Peoria, Ill.
1160	KFJR	259	Stevensville,Mont	1220	KFJY	246	Fort Dodge, Iowa
1160	KGY	259	Lacey, Wash.	1220	KFOJ	246	Moberly, Mo.

1220	KFQS	246	Manitou, Colo.	1270	WTAJ	236	Portland, Me.
1220	WBBH	246	Port Huron, Mich	1280	KFGL	234	Arlington, Ore.
1220	WBBP	246	Petoskey, Mich.	1280	KFJK	234	Bristow, Okla.
1220	WCBR	246	Providence, R. I.	1280	KFKZ	234	Colo.Sprgs., Colo.
1220	WDBF	246	Youngstown, Ohio	1280	KFLW	234	Missoula, Mont.
1220	WEBD	246	Anderson, Ind.	1280	KFNV	234	Santa Rosa, Calif.
1220	WTAT	246	Boston, Mass.	1280	KFOL	234	Marengo, Iowa
1220	WSOE	246	Milwaukee, Wis.	1280	KFON	234	Long Beach, Calif.
1230	KDPT	244	San Diego, Calif.	1280	KFQI	234	Culver City, Calif
1230	WABN	244	La Crosse. Wis.	1280	KFQU	234	Holy City, Calif.
1230	WBAN	244	Paterson, N. J.	1280	KFSG	234	Los Angeles, Calif.
1230	WCBJ	244	Jennings, La.	1280	WABW	234	Wooster, Ohio
1230	WDAY	244	Fargo, N. Dak.	1280	WBBT	234	Philadelphia, Pa.
1230	WNAX	244	Yankton, S. Dak.	1280	WDBQ	234	Salem, N. J.
1230	WRAM	244	Galesburg, Ill.	1280	WDM	234	Washington, D.C.
1230	WWAO	244	Houghton, Mich.	1280	WFAB	234	Syracuse, N. Y.
1240	KFBE	242	San Luis Obispo, Calif.	1280	WIK	234	McKeesport, Pa.
				1280	WLAH	234	Syracuse, N. Y
1240	KFIQ	242	Yakima, Wash.	1280	WQAC	234	Amarillo, Tex.
1240	KFPH	242	Salt Lake C. Utah	1290	KFOZ	232	Fort Smith, Ark.
1240	KFPM	242	Greenville, Tex.	1290	KFQX	232	Seattle, Wash.
1240	KFPN	242	Jefferson City,Mo.	1290	WCBX	232	Newark, N. J.
1240	KFPX	242	Pine Bluff, Ark.	1290	WDBX	232	New York, N. Y.
1240	KFRF	242	Alexandria, La.	1290	WDBZ	232	Kingston, N. Y.
1240	WABY	242	Philadelphia, Pa.	1290	WEBA	232	Highland Prk.,N.J
1240	WCBH	242	Oxford, Miss.	1300	KFDZ	231	Minneapolis,Minn
1240	WEBC	242	Superior, Wis.	1300	KFER	231	Fort Dodge, Iowa
1240	WEBI	242	Salisbury, Md.	1300	KFMT	231	Minneapolis,Minn
1240	WOAV	242	Erie, Pa.	1300	KFNZ	231	Burlingame, Calif.
1240	WRAV	242	Yellow Springs,O.	1300	KFOT	231	Wichita, Kans.
1240	WTAP	242	Cambridge, Ill.	1300	KFPR	231	Los Angeles, Calif.
1240	WWAE	242	Joliet, Ill.	1300	KFPO	231	Denver, Colo.
1240	WTAU	242	Tecumseh, Nebr.	1300	KFQH	231	Hillsbourgh, Calif.
1250	KDZB	240	Bakersfield, Calif.	1300	KFQV	231	Nebraska (Port.)
1250	KFFB	240	Boise, Idaho	1300	WLAX	231	Greencastle, Ind.
1250	KFIX	240	Independence, Mo	1300	WNAR	231	Butler, Mo.
1250	KFLX	240	Galveston, Tex.	1300	WTAX	231	Streator, Ill.
1250	KFNL	240	Paso Robles, Calif	1310	KFLV	229	Rockford, Ill.
1250	KFOF	240	Marshfield, Ore.	1310	WDBB	229	Taunton, Mass.
1250	KFOQ	240	Galveston, Tex.	1310	WDBJ	229	Roanoke, Va.
1250	KFQZ	240	Hollywood, Calif.	1310	WJAB	229	Lincoln, Nebr.
1250	WABH	240	Sandusky, Ohio	1310	WJD	229	Granville, Ohio
1250	WABL	240	Bangor, Me.	1310	WOAR	229	Kenosha, Wis.
1250	WBBA	240	Newark, Ohio	1310	WSAU	229	Chesham, N. H.
1250	WCAT	240	Rapid City, S.Dak	1320	KFQC	227	Taft, Calif.
1250	WCBI	240	Bemis, Tenn.	1320	WBBZ	227	Indianapolis, Ind.
1250	WDBO	240	Winter Park, Fla.	1330	KFDL	225	Denver, Colo.
1250	WEBR	240	Buffalo, N. Y.	1330	KFFR	225	Sparks, Nev.
1250	WFBB	240	Eureka, Ill.	1330	KFGQ	225	Boone, Iowa
1250	WKAD	240	E.Providence,R.I.	1330	KFHD	225	St. Joseph, Mo.
1250	WOAX	240	Trenton, N. J.	1330	KFIU	225	Juneau, Alaska
1250	WQAF	240	Sandusky, Ohio	1330	KFOR	225	David City, Nebr.
1260	KFCB	238	Phoenix, Ariz.	1330	KFOY	225	St. Paul, Minn.
1260	KFPG	238	Los Angeles, Calif.	1330	KFQG	225	Los Angeles, Calif.
1260	WBBD	238	Reading, Pa.	1330	WABU	225	Camden, N. J.
1260	WCBT	238	Worcester, Mass.	1330	WCBW	225	Macon, Ga.
1260	WHAK	238	Clarksburg,W.Va.	1330	WDBI	225	St.Petersburg.Fla.
1260	WRAW	238	Reading, Pa.	1330	WEBL	225	U. S. (Portable)
1270	KFCL	236	Los Angeles, Calif.	1330	WEBQ	225	Harrisburg, Ill.
1270	KFLU	236	San Benito, Tex.	1330	WEBY	225	Roslindale, Mass.
1270	KFOC	236	Whittier, Calif.	1330	WFBN	225	Bridgewater, Mass
1270	KFPP	236	Olympia, Wash.	1330	WKAN	225	Montgomery, Ala.
1270	KFPV	236	San Francisco Cal.	1340	KFBL	224	Everett, Wash.
1270	KFQJ	236	Oklahoma C.Okla.	1340	KFOD	224	Wallace, Idaho
1270	KFQK	236	Fayette, Mo.	1340	KFQE	224	Colo.Sprgs., Colo.
1270	KFRG	236	St. Louis, Mo.	1340	KFQF	224	Minneapolis,Minn
1270	WCBQ	236	Nashville, Tenn.	1340	KFQP	224	Iowa City, Iowa
1270	WDBT	236	Hattiesburg, Miss.	1340	KFRI	224	Denver, Colo.
1270	WFBI	236	Camden, N. J.	1340	WBBU	224	Monmouth, Ill.
1270	WFBJ	236	Collegeville, Minn	1340	WRAF	224	Laporte, Ind.
1270	WPAR	236	Beloit, Kans.	1350	WBBW	222	Norfolk, Va.
1270	WRAN	236	Waterloo, Iowa	1350	WHAG	222	Cincinnati, Ohio

SUPPLEMENTAL LIST OF BROADCASTING STATIONS TO DEC. 12, 1924

ADDITIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFAB	Nebraska Buick Auto. Co.	Lincoln, Nebr.	1250	240	200
KFCC	The First Congregational Church	Helena, Mont.	1210	248	10
KFCY	Western Union College	LeMars, Iowa	1190	252	50
KFDM	Magnolia Petroleum Co.	Beaumont, Tex.	980	306	500
KFHL	Penn College	Oskaloosa, Iowa	1250	240	10
KFNJ	Central Missouri State Teachers College	Warrensburg, Mo.	1280	234	50
KFRL	Men's Club of First Presbyterian Church	Grand Forks, N. D.	1250	240	10
KFRM	James P. Boland	Sort Sill, Okla.	1140	263	50
KFRN	M. Lawrence Short	Hanford, Calif.	1340	224	5
KFRO	Curtis Printing Co.	Fort Worth, Tex.	1220	246	50
KFRP	Trinity Episcopal Church	Redlands, Calif.	1420	211	10
KFRQ	Radio Mark. Service Co.	Portland, Ore.	1410	213	5
KFRW	United. Ch. of Olympia	Olympia, Wash.	1360	220	100
KFRX	J. Gordan Klemgard	Pullman, Wash.	1380	217	10
KFRY	New Mexico College of Agriculture and Mech. Arts	State College, N.M.	1130	266	50
KFRZ	The Electric Shop	Hastington, Nebr.	1350	222	15
KFUL	Thos. Coggan & Brothers, Music Co.	Galveston, Tex.	1160	258	10
KFUM	W. D. Corley	Colo. Sprgs., Colo.	1240	242	100
KFUO	Concordia Seminary	St. Louis, Mo.	550	545	500
KSAC	Kansas State Agri. College	Manhattan, Kans.	880	341	500
WBBM	H. Leslie Atlass	Chicago, Ill.	1330	226	200
WBBS	First Baptist Church	New Orleans, La.	1190	252	50
WCAZ	Carthage College	Carthage, Ill.	1220	246	50
WCEE	Charles E. Erbstein	Elgin, Ill.	560	536	1000
WCM	Texas Market and Warehouse Department	Austin, Tex.	1120	268	250
WFBD	Gethsemane Bapt. Church	Philadelphia, Pa.	1280	234	5
WFBC	First Baptist Church	Knoxville, Tenn.	1200	250	50
WFBE	John Van De Walle	Seymour, Ind.	1330	226	20
WFBQ	Wynne Radio Co.	Raleigh, N. C.	1190	252	50
WFBR	Fifth Infantry Maryland National Guards	Baltimore, Md.	1180	254	50
WFBT	Gloucester County Civic League	Pitman, N. J.	1300	231	50
WFBY	Signal Officer	Fort Benjamin, Harrison, Ind.	1160	258	100
WGBA	Jones Elec. &Radio Mfg.Co	Baltimore, Md.	1180	254	50
WGBC	First Baptist Church	Memphis, Tenn.	1130	266	10
WGBT	Furman University	Greenville, S. C.	1270	236	15
WLB	University of Minnesota	Minneapolis, Minn.	1080	278	5
WNJ*	Radio Shop of Newark	Newark, N. J.	1290	232	10
WOQ	Unity Sch. of Christianity	Kansas City, Mo.	1080	278	500
WRAA	The Rice Institute	Houston, Tex.	1170	256	100
WREO	Reo Motor Car Co.	Lansing, Mich.	1040	288	500
WRHF	Wash. Radio Hospital Fund	Washington, D.C.	1170	256	50
WSAN	Allentown Call Pub. Co.	Allentown, Pa.	1310	229	10
WSY†	Alab. Polytechnic Institute	Auburn, Ala.	1200	250	500

*Old call signal was WCBX.
†Old call signal was WMAV.

CHANGES TO COMPLETE LIST TO DEC. 12, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
KDZR	Bellingham Publishing Co.	Bellingham, Wash...	1300	231	50
KFAR	Studio Lighting Service Co.	Hollywood, Calif...	1320	227	150
KFBB	F. A. Buttrey & Co.......	Havre, Mont.......	1090	275	100
KFCF	Frank A. Moore..........	Walla Walla, Wash.	1170	256	100
KFDX	Frist Baptist Church.......	Shreveport, La......	1200	250	100
KFFY	Louisiana College..........	Alexandria, La......	1090	275	50
KFGD	Chickasha Rad. & Elec.Co.	Chickasha, Okla....	1190	252	50
KFI	Earle C. Anthony (Inc.)...	Los Angeles, Calif..	640	469	1500
KFIQ	First Methodist Church...	Yakima, Wash......	1170	256	50
KFIX	Reorganized Ch. of Jesus Christ of Latter Day Sts.	Independence, Mo..	1120	268	250
KFJF	Nation Radio Mfg. Co.....	Oklahoma C., Okla.	1150	261	225
KFJR	Ralph Schneeloch Co......	Portland, Ore.......	1140	263	50
KFJX	Iowa St. Teachers College.	Cedar Falls, Iowa..	1160	258	50
KFLA	Abner R. Willson..........	Butte, Mont........	1160	258	5
KFMT	Dr. Geo. W. Young........	Minneapolis, Minn..	1300	231	100
KFNV	L. A. Drake Battery and Radio Supply Shop.....	Santa Rosa, Calif...	1320	227	5
KFPG	Oliver S. Garretson........	Los Angeles, Calif...	1260	238	10
KFPW	St. Johns M.E. Church....	Carterville, Mo.....	1120	268	20
KFQE	Dickenson-Henry Rad. Lab	Colorado Sprgs,Colo.	1340	224	10
KFQR	Walter La Fayette Ellis...	Oklahoma C., Okla.	1200	250	50
KFQX	Alfred M. Hubbard........	Seattle, Wash......	1290	232	500
KFSY	The Van Blaricom Co.....	Helena, Mont......	1210	248	10
KJS	Bible Inst. of Los Angeles..	Los Angeles, Calif...	1190	252	500
KQV	Doubleday-Hill Co........	Pittsburgh, Pa......	1090	275	500
KQW	Charles D. Herrold........	San Jose, Calif......	1250	240	50
KYW	Westinghouse Elec. & Mfg. Company..............	Chicago, Ill.........	560	535	1500
WAAF	Chicago Daily Drovers Jour	Chicago, Ill.........	1080	278	200
WBBL	Grace Covenant Church...	Richmond, Va......	1310	229	100
WBZ	Westinghouse Elec. & Mfg. Company..............	Springfield, Mass....	890	337	1500
WCAD	St. Lawrence University...	Canton. N. Y.......	1140	263	250
WCAJ	Nebraska Wesleyan Univ..	Univ. Place, Nebr..	1070	280	500
WCAO	Sanders and Stayman Co..	Baltimore, Md......	1090	275	50
WCAR	So. Radio Corp. of Tex....	San Antonio, Tex...	1140	263	100
WCAU	Durham and Co...........	Philadelphia, Pa....	1080	278	500
WCAV	J. C. Dice Electric Co.....	Little Rock, Ark....	1140	263	10
WCAX	University of Vermont....	Burlington, Vt......	833	360	100
WCBA	Chas. W. Heimbach.......	Allentown, Pa......	1180	254	5
WCBC	University of Michigan....	Ann Arbor, Mich...	1310	229	200
WCBE	Uhalt Bros. Radio Co.....	New Orleans, La....	1140	263	5
WDAE	Tampa Daily Times.......	Tampa, Fla.........	1100	273	250
WDBI	Radio Specialty Co........	St. Petersburg, Fla..	1330	225	20
WDBQ	Morton Radio Supply Co..	Salem, N. J.........	1280	234	50
WEAA	Frank D. Fallain and Police Department...........	Flint, Mich.........	1280	234	50
WEAF	American Tele.& Tel. Co...	New York, N.Y....	610	492	1500
WEAM	Borough of North Plainfield	N.Plainfield, N. J...	1150	261	250
WEAP	Mobile Radio Co., Inc.....	Mobile, Ala.........	1140	263	100
WEB	Benson Radio Co..........	St. Louis, Mo......	1100	273	100
WEBK	Grand Rapids Radio Co...	Grand Rapids, Mich	1240	242	20
WEBW	Beloit College............	Beloit, Wis.........	1120	268	500
WGAQ	Youree Hotel.............	Shreveport, La.....	1140	263	150
WHAG	University of Cincinnati...	Cincinnati, Ohio....	1290	233	200
WHAV	Wilmington Elec. Spec. Co.	Wilmington, Del....	1130	266	100
WJAK	Clifford L. White..........	Greentown, Ind.....	1180	254	50
WJAZ	Zenith Radio Corp.........	Chicago, Ill.........	1120	268	100
WLW	Crosley Radio Corp........	Cincinnati, Ohio....	710	423	1000
WMAC	Clive B. Meredith.........	Casenovia, N. Y....	1090	275	100
WMAK	Norton Laboratories.......	Lockport, N.Y......	1100	273	500

CHANGES TO COMPLETE LIST TO DEC. 12, 1924

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WNAT	Lenning Bros. Co.........	Philadelphia, Pa....	1200	250	100
WQAA	Horace A. Beale, Jr........	Parkesburg, Pa.....	1360	222	500
WQAM	Electric Equipment Co....	Miami, Fla.........	1120	268	100
WQAN	Scranton Times..........	Scranton, Pa.......	1200	250	100
WRAO	St. Louis Rad. Service Co..	St. Louis, Mo......	1320	227	10
WRK	Doron Bros. Elec. Co......	Hamilton, Ohio....	1110	270	200
WRM	University of Illinois......	Urbana, Ill.........	1100	273	500
WRR	City of Dallas Police and Fire Signal Dept.........	Dallas, Tex........	1150	261	200
WSAB*	Southeast Missouri State Teachers College........	Cape Girardeau,Mo.	1090	275	100
WSAP	City Temple Seventh Day Adventist Church......	New York, N.Y....	1140	263	250
WSAZ	Chase Electric Shop......	Pomeroy, Ohio.....	1230	244	50
WSL	J. and M. Electric Co.....	Utica, N. Y.........	1100	273	100
WTAM	Willard Storage BatteryCo.	Cleveland, Ohio....	770	389	1500
WTAR	Reliance Electric Co.......	Norfolk, Va........	1150	261	100
WTAW	Agri. and Mechanical College of Texas...........	College Station, Tex.	1110	270	250
WTAZ	Thomas J. McGuire......	Lambertville, N. J..	1150	261	15
WWAD	Wright & Wright, Inc.....	Philadelphia, Pa....	1200	250	500

*This station was omitted by error from the complete list for November.

Licensed Recently Cancelled

KFFB	KFLW	KUY	WEAR	WMAV*
KFFE	KFOQ	WABE	WFAB	WNAW
KFGL	KFQF	WBBT	WFBU‡	WOQ
KFHD	KFQI	WCBX†	WGAN	WPAM
KFJC	KFQJ	WDAU	WHAK	WTAJ
KFJQ	KFQS	WDBU	WLAH	

†Call changed to WNJ.
‡Cancelled before listing.
*Call changed to WSY and assigned to new owner.

KEEPING UP-TO-DATE

The problem of keeping our list of broadcasting stations up-to-date appears to be more serious now than in the past. The additions, changes and deletions listed in this issue cover a period of but a month and a half.

Many of the changes are due to the desire to use increased power. Others are due to the process continually going on of rectifying past mistakes in frequency assignments. Still others are due to change of ownership.

It is of interest to note that in the list of new stations an effort has been made to assign wherever possible call letters bearing some relation to the initial letters of the individual or firm holding the broadcasting licence. The Reo Motor Car Co. has the call WREO, Chas. E. Erbstein has the call WCEE, etc.

STANDARD FREQUENCY STATIONS

As a result of measurements by the Bureau of Standards upon the transmitted waves of a limited number of radio transmitting stations, data are here given on such of these stations as have been found to maintain a sufficiently constant frequency to be useful as frequency standards. There may be many other stations

Call Signal	Owner and Location of Station	Assigned Frequency Kilocycles	Period Covered by Measurements, Months	No. of Times measured	Average Deviation Per Cent	Greatest Deviation Since Oct. 20, 1924 Per Cent
NSS	United States Navy, Annapolis, Md.	17.50	15	110	0.2	0.5
WGG	Radio Corporation of America, Tuckerton, No. 1, N. J.	18.86	15	119	0.2	0.2
WII	Radio Corporation of America, New Brunswick, N. J.	22.04	14	101	0.2	0.1
WSO	Radio Corporation of America, Marion, Mass.	25.80	15	94	0.3	0.2
WWJ	Detroit News, Detroit Mich.	580	15	46	0.1	0.3
WCAP	Chesapeake & Potomic Tele. Co. Washington, D. C.	640	14	66	0.1	0.2
WRC	Radio Corporation of America, Washington, D. C.	640	11	44	0.1	0.2
WSB	Atlanta Journal, Atlanta, Ga.	700	14	59	0.2	0.9
WGY	General Electric Co., Schenectady, N. Y.	790	17	99	0.2	0.1
WBZ	Westinghouse Elec. & Mfg. Co., Springfield, Mass.	890	7	17	0.0	0.1
KDKA	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.	920	14	126	0.1	0.1

maintaining their frequency just as constant as these, but these are the only ones which reached the degree of constancy shown among the stations upon whose frequencies measurements were made in the bureau's laboratory. There is, of course, no guaranty that the station named here will maintain the constancy shown. As a means of maintaining constant frequency the high-power, low-frequency alternator stations here listed have speed regulators. Most of the broadcasting stations here listed use frequency indicators (one-point wave meters) and maintain a maximum deflection of the frequency indicator throughout the transmission. These broadcasting stations, with rare exceptions, vary not more than 2 kilocycles from the assigned frequency. The transmitted frequencies from these stations can be utilized for standardizing wave meters and other apparatus.

STANDARD RADIO-FREQUENCY TRANSMISSIONS, DECEMBER, JANUARY, FEBRUARY

The Bureau of Standards transmits, twice a month, radio signals of definitely announced frequencies, for use by the public in standardizing wavemeters and transmitting and receiving apparatus. The signals are transmitted from the Bureau's station, WWV, at Washington, D. C., and from station 6XBM, Stanford University, California.

The transmissions are by unmodulated continuous-wave telegraphy. A complete frequency transmission includes a "general call," a "standard frequency signal," and "announcements." The "general call" is given at the beginning of the 8-minute period and continues for about 2 minutes. This includes a statement of the frequency. The "standard frequency signal" is a series of very long dashes with the call letters (WWV or 6XBM) intervening. This signal continues for about 4 minutes. The "announcements" are on the same frequency as the "standard frequency signal" just transmitted and contain a statement of the measured frequency. An announcement of the next frequency to be transmitted is then given. There is then a 4-minute interval while the transmitting set is adjusted for the next frequency.

The signals can be heard and utilized by stations equipped for continuous-wave reception at distances within 500 to 1,000 miles from the transmitting stations. Information on how to receive and utilize the signals is given in Bureau of Standards Letter Circular No. 92, which may be obtained on application from the Bureau of Standards, Washington, D. C.

The schedule of standard frequency signals from both the Bureau of Standards and Stanford University is as follows:

Time*	Dec. 5	Dec. 19	Jan. 5**	Jan. 20	Feb. 5**	Feb. 20
10:00 to 10:08 p.m....	300 (1000)	550 (545)	2000 (150)	1500 (200)	3000 (100)	125 (2400)
10:12 to 10:20 p.m....	315 (952)	650 (461)	2200 (136)	1650 (182)	3300 (91)	133 (254)
10:24 to 10:32 p.m....	345 (869)	750 (400)	2500 (120)	1800 (157)	3600 (83)	143 (2097)
10:36 to 10:44 p.m....	375 (800)	833 (360)	3000 (100)	2000 (150)	4000 (75)	155 (1934)
10:48 to 10:56 p.m....	425 (705)	1000 (300)	3500 (86)	2200 (136)	4400 (68)	166.5 (1800)
11:00 to 11:08 p.m....	500 (600)	1200 (250)	4200 (71)	2450 (122)	** 4900 (61)	205 (1463)
11:12 to 11:20 p.m....	600 (500)	1350 (222)	5100 (59)	2700** (111)	5400 (55)	260 (1153)
11:24 to 11:32 p.m....	666 (450)	1500 (200)	6000 (50)	3000** (100)	6000 (50)	315 (952)

(Approximate wave lengths in meters in parentheses).

*Eastern standard time for WWV, Washington, D. C. Pacific standard time for 6XBM, Stanford University, California.

**The schedules marked with this sign are tentative for station 6XBM, Stanford University; later announcement will be made if there is any change.

BATTERY SWITCH ARRANGEMENT FOR TESTING RADIO SETS

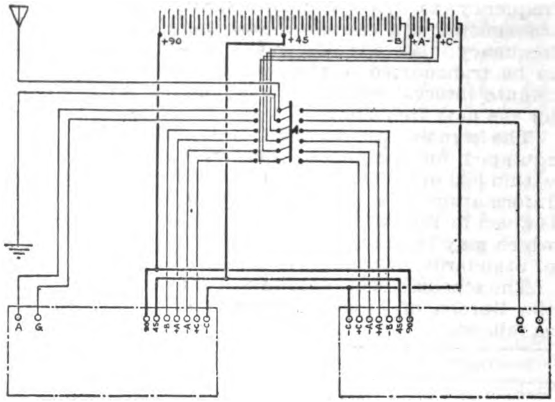
R. H. Langley, General Electric Co.

In making comparison tests between radio sets it is advantageous to have a double throw switch, by which either of two sets may be quickly connected to the antenna and ground and to the batteries. The arrangement of a switch to do this is complicated by the fact that various manufacturers use different methods of connection between the "A," "B" and "C" batteries.

Considering only two plate voltages and one bias voltage, a nine-pole, double-throw switch would seem to be required in order to prevent short circuit of the batteries due to differences in inter-connection in the sets. These nine points would be:

Antenna 90 45 —B +A —A + C—C Ground

An investigation shows that a six-pole switch can be made to do the work, because the 90 volt, the 45 volt, and the —C are all insulated in any receiver. These



three points can, therefore, be omitted from the switch and terminals can be provided for them to which all the sets may be permanently connected, as indicated on the instruction card. The switch will then carry:

Antenna —B +A —A +C Ground

This arrangement has the further decided advantage that terminals can be provided for various "B" and "C" battery voltages and the sets under test can be connected directly to these terminals. For example, terminals can be provided for 22, 45, 90 and 135 volts "B" battery, and for 4½ and 9 volts "C" battery. In as much as opening the switch disconnects the —B and the +C, and disconnects the "A" battery entirely, from all sets, there is no possibility of a short circuit, due to differences in interconnections.

SUPPLEMENTAL LIST OF BROADCASTING STATIONS TO JANUARY 23 1925
ADDITIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFAU‡	Boise High School........	Boise, Idaho.......	1090	275	500
KFKU	The University of Kansas..	Lawrence, Kans....	1090	275	500
KFUJ	Hopport Plumb. & Heat.Co	Breckenridge, Minn.	1240	242	50
KFUP	Fitssimons Gen. Hospital..	Denver, Colo........	1280	234	50
KFUQ	Julius Brunton & Sons Co.	San Francisco,Calif.	1280	234	5
KFUR	H. W. Peery & C. Redfield	Ogden, Utah.......	1340	224	50
KFUS	Louis L. Sherman.........	Oakland, Calif......	1290	233	50
KFUT	Univ. of Utah...........	Salt Lake City, Utah	1150	261	100
KFUU	Colburn Radio Lab........	San Leandro, Calif..	1340	224	100
KOA	General Electric Co........	Denver, Colo.......	930	323	1000
KPPC	Pasadena Presby. Church.	Pasadena, Calif.....	1310	229	50
KTHS	New Arlington Hotel Co..	Hot Springs, Ark...	800	375	500
KZRQ	Far Eastern Radio (Inc.)..	Manila, P. I........	1360	222	500
KZUY	F. Johnson Elser..........	Manila, P. I........	812	370	500
WABA	Lake Forest University....	Lake Forest, Ill.....	1320	227	100
WBCN	Foster & McDonnell......	Chicago, Ill.........	1130	266	500
WBDC	Baxter Laundry Co........	Grand Rapids,Mich.	1170	256	50
WBRE	Baltimore Radio Exchange.	Wilkes Barre, Pa....	1300	231	10
WCBM	Hotel Chateau...........	Baltimore, Md......	1310	229	50
WDBE	Gilham-Schoen Elec. Co...	Atlanta, Ga.........	1080	278	100
WEAR	Goodyear Tire & Rubber C.	Cleveland, Ohio....	770	389	1000
WEBM	Radio Corp. of America...	(Portable) Mobile, Station..........	1330	226	100
WEMC†	Emmanuel MissionaryCol.	Berrien Sprgs., Mich	1050	286	500
WFBZ	Knox College............	Galesburg, Ill.......	1180	254	10
WFUV	G. Pearson Ward.........	Springfield, Mo.....	1190	252	10
WFUW	Earl Wm. Lewis..........	Moberly, Mo.......	1290	233	10
WGBB	Harry H. Carman........	Freeport, N. Y.....	1240	244	100
WGBF	The Finke Furniture Co..	Evansville, Ind.....	1380	217	50
WGBG	Breitenbach's Radio Shop.	Thrifton, Va........	1330	226	100
WGBH	Fall River Herald Pub.Co..	(Portable) in N. Eng States...........	1430	210	10
WGBI	Frank S. Megargee.......	Scranton, Pa.......	1250	240	10
WGBK	Lawrence W. Campbell....	Johnstown, Pa......	1210	248	5
WGBL	Albert H. Ernst..........	Elyria, Ohio........	1320	227	10
WHN**	George Schubel..........	New York, N.Y....	833	360	500
WOCL	Hotel Jamestown, Inc.....	Jamestown, N.Y....	1090	275	15
WORD	Peoples Pulpit Assn.......	Batavia, Ill.........	1080	278	500
WPG	Municp. of Atlantic City..	Atlantic City, N.J..	1010	296	500
WPSC*	Pennsylvania State College	State College, Pa...	1150	261	500
WSAG	Loren Vanderbeck Davis..	St. Petersburg, Fla..	1130	266	500
WSRF	Harden Sales & Service....	Broadlands, Ill.....	1290	233	10
WTIC	The Travelers Ins. Co.....	Hartford, Conn.....	860	349	500

‡Reported cancelled in August, 1924, issue of Radiofax, reinstated January, 1925.
†Old call signal was KFGZ.
*Old call signal was WPAB.
**Formerly listed as Loews State Theatre Studio.

LICENCES RECENTLY CANCELLED

KDZR	KFOF	KFRI	WABP	WPAR
KFAY	KFPN	KGG	WBL	WQAF
KFBE	KFPO	KJS	WEBU	WQAX
KFBS	KFQK	KQP	WIAB	WRL
KFGZ*	KFQO		WPAB†	
KFKZ	KFRG			

*Call changed to WEMC. †Call changed to WPSC.

CHANGES TO COMPLETE LIST TO JANUARY 23 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDYL	Newhouse Hotel..........	Salt Lake City, Utah	1200	250	50
KFBG	First Presbyterian Church.	Tacoma, Wash.....	1200	250	50
KFBU	Bishop N. S. Thomas......	Laramie, Wyo.......	1110	270	50
KFDJ	Oregon Agricultural College	Corvallis, Ore.......	1180	254	50
KFFV	Graceland College.........	Lamoni, Iowa.......	1200	250	100
KFIF	Benson Polytech. School..	Portland, Ore.......	1210	248	100
KFMQ	Univ. of Arkansas.........	Fayetteville, Ark...	1090	275	500
KFOY	Beacon Radio Service......	St. Paul, Minn......	1190	252	50
KFRC	Radioart Studio...........	San Francisco, Calif.	1080	278	50
KFQC	Kidd Bros. Radio Shop...	Taft, Calif..........	1300	231	100
KFQG	South. Calif. Radio Ass'n..	Los Angeles, Calif..	1310	229	50
KGB	Tacoma Daily Ledger......	Tacoma, Wash......	1200	250	50
KFGC	Louisiana State University.	Baton Rouge, La...	1120	268	100
KGO	General Electric Co.......	Oakland, Calif......	960	312	1500
KMO	Love Electric Co..........	Tacoma, Wash......	1200	250	10
KOP	Detroit Police Dept.......	Detroit, Michigan..	1090	278	500
KUO	Examiner Printing Co.....	San Francisco, Calif.	1220	246	150
WAAC	Tulane University.........	New Orleans, La....	1090	275	100
WAAD	Ohio Mechanics Inst.......	Cincinnati, Ohio....	1160	258	25
WAAW	Omaha Grain Exchange...	Omaha, Nebr........	1080	278	500
WABM	F. E. Dougherty..........	Saginaw, Michigan..	1150	261	20
WABO	Lake Ave. Baptist Church.	Rochester, N.Y.....	1080	278	100
WABR	Scott High School.........	Toledo, Ohio.......	1140	263	50
WABW	The Coll. of Wooster Physics Department....	Wooster, Ohio......	1450	207	20
WABX	Henry B. Joy............	Mt. Clemens, Mich.	1180	254	50
WBAX	John H. Stenger, Jr.......	Wilkes Barre, Pa...	1170	256	20
WBBA	Plymouth Congreg. Church	Newark, Ohio.......	1330	226	20
WBBH	J. Irving Bell............	Port Huron, Mich...	1460	205	50
WBBP	Petoskey High School.....	Petoskey, Mich.....	1400	214	5-100
WBT	Southern Radio Corp......	Charlotte, N.C......	1090	275	250
WCAH	Entrekin Electric Co......	Columbus, Ohio....	1130	266	200
WCAL	St. Olaf Coll. Physics Dept.	Northfield, Minn....	890	337	500
WCBI	Nicell, Duncan & Rush....	Bemis, Tenn........	1250	240	150
WCBR	Charles H. Messter........	Providence, R.I.....	1220	246	30
WCBU	Arnold Wireless Sup. Co...	Arnold, Pa..........	1340	220	50
WCK	Stix, Baer & Fuller Co.....	St. Louis, Mo.......	1100	273	100
WDBS	The S.M.K. Radio Corp...	Dayton, Ohio.......	1090	275	5
WDZ	James L. Bush............	Tuscola, Ill.........	1080	278	10-100
WEAF	American Tel.&Tel. Co....	New York, N.Y....	610	492	2000
WEAH	Wichita Board of Trade...	Wichita, Kans......	1120	268	100
WEAI	Cornell University.........	Ithaca, N. Y........	1180	254	500
WEAJ	Univ. of South Dakota....	Vermillion, S. Dak..	1080	278	100
WEBO	Radio Company..........	Hamilton, Ohio....	1190	252	5
WEBT	The Dayton Co-op. Indus. High School............	Dayton, Ohio......	1170	256	5
WEBZ	Savannah Radio Corp.....	Savannah, Ga.......	1280	234	5
WFBG	Wm. F. Gable Co.........	Altoona, Pa.........	1080	278	100
WFBL	Onondaga Hotel Co.......	Syracuse, N.Y......	1190	252	100
WGY	General Electric Co.......	Schnectady, N.Y....	790	380	1500
WHA	Univ. of Wisconsin.......	Madison, Wis.......	560	535	500
WHAD	Marquette University.....	Milwaukee, Wis....	1900	275	500
WHAM	University of Rochester...	Rochester, N.Y.....	1080	278	100
WHN**	George Schubel...........	New York, N. Y....	833	360	500
WJAD	Frank P. Jackson.........	Waco, Texas........	850	353	500
WJAG	The Norfolk Daily News Co	Norfolk, Neb.......	1110	270	250
WJAN	Peoria Star Co...........	Peoria, Ill..........	1100	273	100
WJAS	Pittsburgh Radio Sup. Hse.	Pittsburgh, Pa......	1090	275	500
WJD	Denison University.......	Granville, Ohio.....	1380	217	10
WJJD	Supreme Lodge L.O.O.M..	Mooseheart. Ill.....	990	303	500
WKY	WKY Radio Shop.........	OklahomaCity,Okla.	1090	275	100
WMAK	Norton Laboratories......	Lockport, N.Y......	1130	266	500
WMAN	First Baptist Church......	Columbus, Ohio....	1080	278	50
WNAC	Shepard Stores...........	Boston, Mass.......	1070	280	500

**Formery listed as Loews State Theatre Studio.

BROADCASTING STATIONS BY FREQUENCY

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
550	KFUO	545	St. Louis, Mo.			
550	KSD	545	St. Louis, Mo.			
560	KYW	535	Chicago, Ill.			
560	WHA	535	Madison, Wis.			
570	WHO	526	Des Moines, Iowa			
570	WNYC	526	New York City, N.Y.			
570	WOAW	526	Omaha, Nebr.			
580	WCX	517	Detroit, Mich.			
588	KLX	510	Oakland, Calif.			
590	WIP	508	Philadelphia, Pa.			
590	WOO	508	Philadelphia, Pa.			
600	WMC	500	Memphis, Tenn.			
610	KGW	492	Portland, Ore.			
610	WEAF	492	New York City, N.Y.			
620	WOC	484	Davenport, Iowa			
620	WSUI	484	Iowa City, Iowa			
630	WBAP	476	Fort Worth, Texas			
630	WEEI	476	Boston, Mass.			
630	WFAA	476	Dallas, Texas			
640	WCAP	469	Washington, D. C.			
640	WRC	469	Washington, D. C.			
642	KFI	467	Los Angeles, Calif.			
650	WCAE	461	Pittsburgh, Pa.			
660	WJZ	454	New York City, N.Y.			
666	KFOA	450	Seattle, Wash.			
670	WMAQ	448	Chicago, Ill.			
670	WQJ	448	Chicago, Ill.			
680	WDWF	441	Cranston, R. I.			
680	WOS	441	Jefferson City, Mo.			
698	KPO	430	San Francisco, Calif.			
700	WSB	428	Atlanta, Ga.			
710	WLW	422	Cincinnati, Ohio			
710	WMH	422	Cincinnati, Ohio			
720	WCCO	416	Minneapolis, Minn.			
740	WJY	405	New York City, N.Y.			
740	WOR	405	Newark, N. J.			
742	KHJ	404	Los Angeles, Calif.			
750	WHAS	400	Louisville, Ky.			
760	WGY	395	Schenectady, N. Y.			
760	WFI	395	Philadelphia, Pa.			
760	WOAI	395	San Antonio, Texas			
760	WLIT	395	Philadelphia, Pa.			
770	WEAR	389	Cleveland, Ohio			
770	WTAM	389	Cleveland, Ohio			
780	KJR	384	Seattle, Wash.			
780	WMBF	384	Miami Beach, Fla.			
790	WHAZ	380	Troy, N. Y.			
800	KTHS	375	Hot Springs, Ark.			
810	WEBH	370	Chicago, Ill.			
810	WGN	370	Chicago, Ill.			
820	WDAF	366	Kansas City, Mo.			
820	WHB	366	Kansas City, Mo.			
833	KFAD	360	Phoenix, Ariz.			
833	KFCP	360	Ogden, Utah			
833	KFHJ	360	Santa Barbara, Calif.			
833	KGU	360	Honolulu, Hawaii			
833	KLS	360	Oakland, Calif.			
833	KTW	360	Seattle, Wash.			
833	KWG	360	Stockton, Calif.			
833	KWH	360	Los Angeles, Calif.			
833	KZM	360	Oakland, Calif.			
833	WBS	360	Newark, N. J.			
833	WEAY	360	Houston, Tex.			
833	WHN	360	New York City, N.Y.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
833	WMAF	360	South Dartmouth, Mass			
833	WOAF	360	Tyler, Texas			
833	WQAO	360	New York City, N.Y.			
833	WRL	360	Schenectady, N. Y.			
833	WSAV	360	Houston, Tex.			
850	WJAD	353	Waco, Texas			
850	WWJ	353	Detroit, Mich.			
860	KOB	349	State College, N. Mex.			
860	WTIC	349	Hartford, Conn.			
870	WCBD	345	Zion, Ill.			
870	WLS	345	Chicago, Ill.			
880	KSAC	341	Manhattan, Kan.			
880	WKAQ	341	San Juan, Porto Rico			
890	KFMX	337	Northfield, Minn.			
890	KNX	337	Los Angeles, Calif.			
890	WCAL	337	Northfield, Minn.			
890	WSAC	337	Clemson College, S C.			
900	KFAE	333	Pullman, Wash.			
900	WBZ	333	Springfield, Mass.			
920	WSAI	326	Cincinnati, Ohio			
930	KOA	322	Denver, Colo.			
940	WGR	319	Buffalo, N. Y.			
950	KFDM	316	Beaumont, Texas			
950	WAHG	316	Richmond Hill, N.Y.			
950	WGBS	316	New York City, N.Y.			
970	KDKA	309	E. Pittsburgh, Pa.			
980	KUYL	306	Salt Lake City, Utah			
980	WJAR	306	Providence, R. I.			
990	WJJD	303	Mooseheart, Ill.			
990	WTAS	303	Elgin, Ill.			
1000	KFKU	300	Lawrence, Kans.			
1000	KFMQ	300	Fayetteville, Ark.			
1000	KGO	300	Oakland, Calif.			
1000	WPG	300	Atlantic City, N.J.			
1010	KFRU	297	Bristow, Okla.			
1020	KJS	294	Los Angeles, Calif.			
1020	WBAV	294	Columbus, Ohio			
1020	WEAO	294	Columbus, Ohio			
1040	KFKX	288	Hastings, Nebr.			
1050	KFGZ	286	Berrien Springs, Mich.			
1050	WEMC	286	Berrien Springs, Mich.			
1050	WKAR	286	East Lansing, Mich.			
1050	WLAP	286	Louisville, Ky.			
1050	WREO	286	Lansing, Mich.			
1060	KFBK	283	Sacramento, Calif.			
1060	KFKV	283	Butte, Mont.			
1060	KFQN	283	Portland, Ore.			
1060	KLZ	283	Denver, Colo.			
1060	WOAN	283	Lawrenceburg, Tenn.			
1060	WPAB	283	State College, Pa.			
1070	KDYM	280	San Diego, Calif.			
1070	KFAW	280	Santa Ana, Calif.			
1070	KFQD	280	Anchorage, Alaska			
1070	WEBP	280	New Orleans, La.			
1070	WNAC	280	Boston, Mass.			
1080	KFAF	278	Denver, Colo.			
1080	KFBC	278	San Diego, Calif.			
1080	KFJM	278	Grand Forks, N. D.			
1080	KFSG	278	Los Angeles, Calif.			
1080	KFRC	278	San Francisco, Calif.			
1080	KFSG	278	San Francisco, Calif.			
1080	WAAF	278	Chicago, Ill.			
1080	WAAW	278	Omaha, Nebr.			
1080	WABO	278	Rochester, N. Y.			
1080	WCAU	278	Philadelphia, Pa.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings
1080	WDBE	278	Atlanta, Ga.	
1080	WDZ	278	Tuscola, Ill.	
1080	WEAJ	278	Vermillion, S. D.	
1080	WFBG	278	Altoona, Pa.	
1080	WHAM	278	Rochester, N. Y.	
1080	WHDI	278	Indianapolis, Minn.	
1080	WIAK	278	Omaha, Nebr.	
1080	WKAA	278	Cedar Rapids, Iowa.	
1080	WLB	278	Minneapolis, Minn.	
1080	WLBL	278	Stevens Pt., Wis.	
1080	WMAN	278	Columbus, Ohio.	
1080	WRBC	278	Valparaiso, Ind.	
1080	WOQ	278	Kansas City, Mo.	
1080	WORD	278	Batavia, Ill.	
1090	KFAU	275	Boise, Idaho.	
1090	KFBB	275	Havre, Mont.	
1090	KFDD	275	Boise, Idaho.	
1090	KFFY	275	Alexandria, La.	
1090	KFMQ	275	Fayetteville, Ark.	
1090	KOP	278	Detroit, Mich.	
1090	KQV	275	Pittsburgh, Pa.	
1090	KRE	275	Berkeley, Calif.	
1090	WAAC	275	New Orleans, La.	
1090	WABL	275	Storrs, Conn.	
1090	WBAO	275	Decatur, Ill.	
1090	WCAO	275	Baltimore, Md.	
1090	WBT	275	Charlotte, N. C.	
1090	WCEE	275	Elgin. Ill.	
1090	WCAJ	275	University Place, Nebr.	
1090	WDBS	275	Dayton, Ohio.	
1090	WEAU	275	Sioux City, Iowa.	
1090	WFAV	275	Lincoln, Nebr.	
1090	WGAZ	275	South Bend, Ind.	
1090	WGBO	275	San Juan, Porto Rico.	
1090	WHAD	275	Milwaukee, Wis.	
1090	WHAR	275	Atlantic City, N.J.	
1090	WJAS	275	Pittsburgh, Pa.	
1090	WKY	275	Oklahoma City, Okla.	
1090	WMAC	275	Cazenovia, N. Y.	
1090	WOCL	275	Jamestown, N. Y.	
1090	WPAK	275	Fargo, N. Dak.	
1090	WSAB	275	Cape Girardeau, Mo.	
1090	WWL	275	New Orleans, La.	
1100	KFDY	273	Brookings, S. Dak.	
1100	KFGH	273	Stanford Univ., Calif.	
1100	KFIZ	273	Fond du Lac, Wis.	
1100	KFKA	273	Greeley, Colo.	
1100	KFKB	273	Milford, Kans.	
1100	KFLZ	273	Atlantic, Iowa.	
1100	KFQY	273	Belden, Nebr.	
1100	KHQ	273	Seattle, Wash.	
1100	KJQ	273	Stockton, Calif.	
1100	WBAA	273	W. Lafayette, Ind.	
1100	WBBR	273	Rossville, N. Y.	
1100	WCK	273	St. Louis, Mo.	
1100	WDAE	273	Tampa, Fla.	
1100	WEBJ	273	New York City, N.Y.	
1100	WFAM	273	St. Cloud, Minn.	
1100	WFBH	273	New York City, N.Y.	
1100	WHK	273	Cleveland, Ohio.	
1100	WJAN	273	Peoria, Ill.	
1100	WRM	273	Urbana, Ill.	
1100	WRW	273	Tarrytown, N. Y.	
1100	WSL	273	Utica, N. Y.	

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1100	WTG	273	Manhattan, Kans.			
1110	KDZE	270	Seattle, Wash.			
1110	KYQ	270	Honolulu, Hawaii			
1110	KZKZ	270	Manila, P.I.			
1110	WEAN	270	Providence, R. I.			
1110	WGST	270	Atlanta, Ga.			
1110	WJAG	270	Norfolk, Nebr.			
1110	WOI	270	Ames, Iowa			
1110	WRK	270	Hamilton, Ohio			
1110	WTAW	270	College Station, Tex.			
1120	KFEQ	268	Oak, Nebr.			
1120	KFGC	268	Baton Rouge, La.			
1120	KFLE	268	Denver, Colo.			
1120	KFPW	268	Carterville, Mo.			
1120	KFQM	268	Austin, Texas			
1120	KFRH	268	Grafton, N. Dak.			
1120	KLDS	268	Independence, Mo.			
1120	WAAB	268	New Orleans, La.			
1120	WBBY	268	Charleston, S. C.			
1120	WCAG	268	New Orleans, La.			
1120	WCBG	268	Pascagoula, Miss.			
1120	WCBY	268	Buck Hill Falls, Pa.			
1120	WCM	268	Austin, Texas			
1120	WCTS	268	Worcester, Mass.			
1120	WDAH	268	El Paso, Texas			
1120	WDBW	268	Columbia, Tenn.			
1120	WEAH	268	Wichita, Kansas			
1120	WEBW	268	Beloit, Wis.			
1120	WFBM	268	Indianapolis, Ind.			
1120	WJAM	268	Cedar Rapids, Iowa			
1120	WJAZ	268	Chicago, Ill.			
1120	WPAJ	268	New Haven, Conn.			
1120	WPAZ	268	Charleston, W. Va.			
1120	WQAM	268	Miami, Fla.			
1120	WRAX	268	Goucester City, N. J.			
1120	WSAX	268	Chicago, Ill.			
1120	WTAF	268	New Orleans, La.			
1130	KFFP	265	Moberly, Mo.			
1130	KFIO	265	Spokane, Wash.			
1130	KFMW	265	Houghton, Mich.			
1130	KFNF	265	Shenandoah, Iowa			
1130	KFPY	266	Spokane, Wash.			
1130	KFRY	265	State College, N. M.			
1130	WABB	265	Harrisburg, Pa.			
1130	WBCN	266	Chicago, Ill.			
1130	WCAH	265	Columbus, Ohio			
1130	WCAY	265	Milwaukee, Wis.			
1130	WCBL	265	Houlton, Me.			
1130	WGBC	265	Memphis, Tenn.			
1130	WHAV	265	Wilmington, Del.			
1130	WMAK	266	Lockport, N. Y.			
1130	WOAC	265	Lima, Ohio			
1130	WSAG	265	St. Petersburg, Fla.			
1130	WTAB	265	Fall River, Mass.			
1130	WWI	265	Dearborn, Mich.			
1140	KFHR	263	Seattle, Wash.			
1140	KFJR	263	Portland, Ore.			
1140	KFMT	263	Minneapolis, Minn.			
1140	KFRM	263	Fort Sill, Okla.			
1140	KNT	263	Kukak Bay, Alaska			
1140	WAAM	263	Newark, N. J.			
1140	WABR	263	Toledo, Ohio			
1140	WABZ	263	New Orleans, La.			
1140	WCAD	263	Canton, N. Y.			

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LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Corrected to February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse E. & M. Co.	East Pittsburgh, Pa.	970	309	1000
KDLR	The Radio Elec. Co.	Devils Lake, N.Dak.	1300	231	5
KDPM	Westinghouse E. & M. Co.	Cleveland, Ohio	1200	250	500
KDPT	Southern Electrical Co.	San Diego, Calif.	1230	244	50
KDYL	Newhouse Hotel	Salt Lake City, Utah	980	306	50
KDYM	Savoy Theatre	San Diego, Calif.	1070	280	100
KDZB	Frank E. Siefert	Bakersfield, Calif.	1250	240	100
KDZE*	The Rhodes Dept. Store	Seattle, Wash.	1110	270	100
KFAB	Nebraska Buick Auto Co	Lincoln, Nebr.	1250	240	200
KFAD	McArthur Bros. Co.	Phoenix, Ariz.	833	360	100
KFAE	State College of Wash.	Pullman, Wash.	900	333	500
KFAF	Western Radio Corp.	Denver, Colo.	1080	278	500
KFAJ	University of Colorado	Boulder, Colo.	1150	261	100
KFAN	University of Moscow	Moscow, Idaho	1300	231	50
KFAU	Boise High School	Boise, Idaho	1090	275	500
KFAW	The Radio Den	Santa Ana, Calif.	1070	280	10
KFBB	F. A. Buttrey & Co.	Havre, Mont.	1090	275	50
KFBC	W. K. Azbill	San Diego, Calif.	1080	278	5
KFBG	First Presbyterian Church	Tacoma, Wash.	1200	250	50
KFBK	Kimball-Upson Co.	Sacramento, Calif.	1060	283	100
KFBL	Leese Bros.	Everett, Wash.	1340	224	15
KFBU	Bishop N. S. Thomas	Laramie, Wyo.	1110	270	50
KFCB	Nielson Radio Supply Co.	Phoenix, Ariz.	1260	238	10
KFCC	The 1st Congreg. Church	Helena, Mont.	1210	248	10
KFCF	Frank A. Moore	Walla Walla, Wash.	1170	256	100
KFCL	Leslie E. Rice	Los Angeles, Calif.	1270	236	500
KFCP	Ralph W. Flygare	Ogden, Utah	833	360	10
KFCY	Western Union College	Le Mars, Iowa	1190	252	50
KFCZ	Omaha Central High Sch.	Omaha, Nebr.	1160	259	50
KFDD	St. Michael Cathedral	Boise, Idaho	1090	275	10
KFDH	University of Arizona	Tucson, Ariz.	1160	259	50
KFDJ	Oregon Agri. College	Corvallis, Ore.	1180	254	50
KFDL	Knight Campbell Mus.Co.	Denver, Colo.	1330	225	5
KFDM	Magnolia Petroleum Co.	Beaumont, Texas	950	316	500
KFDX	First Baptist Church	Shreveport, La.	1200	250	100
KFDY	S. Dak. State College of Agri. & Mechanic Arts	Brookings, S. Dak.	1100	273	100
KFDZ	Harry O. Iverson	Minneapolis, Minn.	1300	231	5
KFEC	Meier & Frank Co.	Portland, Ore.	1210	248	50
KFEL	Winner Radio Corp.	Denver, Colo.	1180	254	150
KFEQ	J. L. Scroggin	Oak, Nebr.	1120	268	100
KFER	Auto. Elec. Service Co.	Fort Dodge, Iowa	1300	231	10
KFEX	Augsburg Seminary	Minneapolis, Minn.	1150	261	100
KFEY	Bunker Hill & Sullivan Min. & Concentr. Co.	Kellogg, Idaho	1290	232	10
KFFP	First Baptist Church	Moberly, Mo.	1130	265	50
KFFR	Nevada State Journal	Sparks, Nev.	1330	225	10
KFFV	Graceland College	Lamoni, Iowa	1200	250	100
KFFY	Louisiana College	Alexandria, La.	1090	275	50
KFGC	Louisiana State Univ.	Baton Rouge, La.	1120	268	100
KFGD	Okla. College for Women	Chickasha, Okla.	1190	252	50
KFGH	Leland Stanford University	Stanford Univ. Calif.	1100	273	500
KFGQ	Crary Hardware Co.	Boone, Iowa	1330	225	10
KFGX	First Presbyterian Church	Orange, Texas	1200	250	500
KFHA	Western State Col. of Colo.	Gunnison, Colo.	1190	252	50
KFHJ	Fallon & Company	Santa Barbara, Calif.	833	360	100
KFHL	Penn College	Oskaloosa, Iowa	1250	240	10
KFHR	Star Elec. & Radio Co.	Seattle, Wash.	1140	263	100
KFI	Earle C. Anthony, Inc.	Los Angeles, Calif.	642	467	1500
KFIF	Benson Polytechnic School	Portland, Ore.	1210	248	100

*This Company also operates station KFOA.

Active Broadcasting Stations February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFIO	North Central High School	Spokane, Wash.....	1130	265	50
KFIQ	First Methodist Church...	Yakima, Wash......	1170	256	50
KFIU	Alaska Elec.Light&Pr. Co.	Juneau, Alaska.....	1330	225	10
KFIZ	Daily Commonwealth and Seifert Radio Corp.......	Fond du Lac, Wis..	1100	273	100
KFJB	Marshall Elec. Co.........	Marshalltown, Iowa	1210	248	10
KFJF	Nation Radio Mfg. Co.....	Oklahoma City, Okla	1150	261	225
KFJI	Liberty Theatre, E.E.Marsh	Astoria, Ore.........	1190	252	10
KFJM	Univ. of North Dakota....	Grand Forks, N.Dak	1080	278	100
KFJR	Ralph Schneeloch Co.......	Portland, Ore.......	1140	263	5
KFJX	Iowa State Teachers Col...	Cedar Falls, Iowa...	1160	259	50
KFJY	Tunwall Radio Co.........	F. Dodge, Iowa....	1220	246	50
KFJZ	Tex. Nat. Guard 112th Cal.	Ft. Worth, Texas...	1180	254	20
KFKA	Colo. State Teach. College.	Greeley, Colo.......	1100	273	50
KFKB	Brinkley-JonesHospitalAss.	Milford, Kans.......	1100	273	500
KFKQ	Conway Radio Labs.........	Conway, Ark........	1200	250	100
KFKU	The University of Kansas.	Lawrence, Kans....	1090	275	500
KFKV	F. F. Gray................	Butte, Mont.........	1060	283	50
KFKX	Westinghouse E. & M. Co.	Hastings, Nebr.....	1040	288	1000
KFLA	Abner R. Willson..........	Butte, Mont.........	1160	259	5
KFLB	Signal Electric Mfg. Co...	Menominee, Mich..	1210	248	50
KFLE	National Educ. Service....	Denver, Colo......	1120	268	25
KFLP	Everette M. Foster.......	Cedar Rapids, Iowa.	1170	256	20
KFLR	Univ. of New Mexico......	Albuquerque, N.M..	1180	254	100
KFLU	San Benito Radio Club....	San Benito, Texas..	1270	236	15
KFLV	Swedish Evang. Miss. Chr.	Rockford, Ill........	1310	229	100
KFLX	George Roy Clough.......	Galveston, Texas...	1250	240	10
KFLZ	Atlantic Automobile Co....	Atlantic, Iowa......	1100	273	100
KFMB	Christian Churches of Little Rock...............	Little Rock, Ark....	1180	254	50
KFMQ	Univ. of Arkansas.........	Fayetteville, Ark....	1000	300	500
KFMR	Morningside College.......	Sioux City, Iowa...	1150	261	10
KFMT	Dr. Geo. W. Young.......	Minneapolis, Minn..	1140	263	100
KFMW	M. G. Sateren............	Houghton, Mich....	1130	265	50
KFMX	Carleton College..........	Northfield, Minn...	890	337	750
KFNF	Henry Field Seed Co......	Shenandoah, Iowa..	1130	265	500
KFNG	Wooten's Radio Shop.....	Coldwater, Miss....	1180	254	10
KFNJ	Central Miss. State Teachers' College............	Warrensburg, Mo...	1280	234	50
KFNL	Radio Broadcast. Ass'n...	Paso Robles, Calif..	1250	240	10
KFNV	L. A. Drake Battery & Radio Supply Shop.........	Santa Rosa, Calif...	1320	227	5
KFNY	Montana Phonograph Co...	Helena, Mont.......	1210	248	50
KFNZ	Royal Radio Company....	Burlingame, Calif...	1300	231	10
KFOA*	The Rhodes Dept. Store...	Seattle, Wash......	666	450	500
KFOC	First Christian Church....	Whittier, Calif......	1270	236	100
KFOD	The Radio Shop..........	Wallace, Idaho.....	1340	224	10
KFOJ	Moberly High Sch. Rad. Cl.	Moberly, Mo........	1220	246	5
KFOL	Leslie M. Schafbuch.......	Marengo, Iowa.....	1280	234	10
KFON	Echophone Radio Shop....	Long Beach, Calif...	1280	234	100
KFOO	Latter Day Saints Univ....	Salt Lake City, Utah	1150	261	5
KFOR	David City Tire&Elec.Co..	David City, Nebr...	1330	225	20
KFOT	College Hill Radio Club...	Wichita, Kans......	1300	231	50
KFOU	Hommel Mfg. Co.........	Richmond, Calif....	1180	254	100
KFOX	Board of Ed. Tech. High S.	Omaha, Nebr.......	1210	248	100
KFOY	Beacon Radio Service.....	St. Paul, Minn.....	1190	252	50
KFPG	Oliver S. Garretson.......	Los Angeles, Calif..	1260	238	10
KFPH	Harold C. Mailander......	Salt Lake City, Utah	1240	242	50
KFPL	C. C. Baxter.............	Dublin, Texas......	1190	252	15
KFPM	The New Furniture Co....	Greenville, Texas...	1240	242	10
KFPR	Los Angeles Co., Forestry Department...........	Los Angeles, Calif...	1300	231	500
KFPT	Rad. Service Corp. of Utah	Salt Lake City, Utah	1150	261	500
KFPV	Heintz & Kohlmoos, Inc..	San Francisco, Calif.	1270	236	50

*This Company also operates station KDZE.

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFPW	St. Johns M. E. Church	Carterville, Mo.	1120	268	20
KFPX	First Presbyterian Church	Pine Bluff, Ark.	1240	242	100
KFPY	Symons Investment Co.	Spokane, Wash.	1030	266	100
KFQA	The Principia	St. Louis, Mo.	1150	261	50
KFQB	The Searchlight Pub. Co.	Fort Worth, Texas.	1180	254	100
KFQC	Kidd Bros. Radio Shop	Taft, Calif.	1300	231	100
KFQD	Chovin Supply Co.	Anchorage, Alaska.	1070	280	100
KFQE	Dickenson-Henry Rad. Co.	Colo. Springs, Colo.	1340	224	10
KFQG	Southern Cal. Rad. Ass'n.	Los Angeles, Calif.	1310	229	50
KFQH	Radio Service Co.	Burlingame, Calif.	1300	231	50
KFQM	Texas Highway Bulletin	Austin, Texas	1120	268	100
KFQN	Third Baptist Church	Portland, Ore.	1060	283	5
KFQP	Geo. S. Carson, Jr.	Iowa City, Iowa	1340	224	10
KFQR	Walter La Fayette Ellis	OklahomaCity,Okla.	1430	210	50
KFQT	Texas National Guard	Denison, Texas	1190	252	10
KFQU	W. Riker	Holy City, Calif.	1280	234	100
KFQW	C. F. Knieria	North Bend, Wash.	1390	216	50
KFQX	Alfred M. Hubbard	Seattle, Wash.	1290	232	500
KFQY	Farmers' State Bank	Belden, Nebr.	1100	273	10
KFQZ	Taft Radio Co.	Hollywood, Calif.	1250	240	250
KFRB	Hall Brothers	Beeville, Texas	1210	248	250
KFRC	Radioart Studio	San Francisco, Calif.	1080	278	50
KFRF	W. R. Brown	Alexandria, La.	1240	242	10
KFRH	The Radio Shop	Grafton, N. Dak.	1120	268	10
KFRJ	Guy Simmons, Jr.	Conway, Ark.	1200	250	10
KFRL	Men's Club of First Pres. Church	Grand Forks, N.Dak	1250	240	10
KFRM	James P. Boland	Fort Sill, Okla.	1140	263	50
KFRN	M. Lawrence Short	Hanford, Calif.	1340	224	5
KFRO	Curtis Printing Co.	Fort Worth, Texas.	1220	246	50
KFRP	Trinity Episcopal Church	Redlands, Calif.	1420	211	10
KFRQ	Radio Market Service Co.	Portland, Ore.	1410	213	5
KFRU	Etherical Studios	Bristow, Okla.	1110	297	500
KFRW	Unit. Churches of Olympia	Olympia, Wash.	1360	220	100
KFRX	J. Gordon Klemgard	Pullman, Wash.	1380	217	10
KFRY	N. Mex. College of Agriculture & Mechanic Arts	State College, N. M.	1130	265	50
KFRZ	The Electric Shop	Hartington, Nebr.	1350	222	15
KFSG	Echo Prk Evangel. Ass'n.	Los Angeles, Calif.	1080	278	500
KFSY	The Van Blarisom Co.	Helena, Mont.	1210	248	10
KFUJ	Hopport Plumb. & Heating Company	Breckenridge, Minn.	1240	242	50
KFUL	Thos. Coggan&Bros.Mu.Co	Galveston, Texas	1160	259	10
KFUM	W. D. Corley	Colo. Springs, Colo.	1240	242	100
KFUO	Concordia Seminary	St. Louis, Mo.	550	545	500
KFUP	Fitzsimons Gen. Hospital	Denver, Colo.	1280	234	50
KFUQ	Julius Brunton&Sons Co.	San Francisco, Calif.	1280	234	5
KFUR	H. W. Peery&C. Redfield	Ogden, Utah	1340	224	50
KFUS	Louis L. Sherman	Oakland, Calif.	1290	232	50
KFUT	University of Utah	Salt Lake City, Utah	1150	261	100
KFUU	Colburn Rad. Laboratories	San Leandro, Calif.	1340	224	100
KFUV	G. Pearson Ward	Springfield, Mo.	1190	252	10
KFUW	E. W. Lewis	Moberly, Mo.	1290	233	10
KFUY	Irvine H. Bouchard	Butte, Mont.	1180	254	5
KFUZ	Y. M. C. A.	Virginia, Minn.	1210	248	10
KFVF	Clarence B. Juneau	Hollywood, Calif.	1440	208	10
KFWB	Warner Bros. Pictures, Inc.	Hollywood, Calif.	1190	252	500
KFWC	L. E. Wall & C. S. Myers	Upland, Calif.	1420	211	10
KGB	Tacoma Daily Ledger	Tacoma, Wash.	1200	250	50
KGO	General Electric Co.	Oakland, Calif.	1000	300	2000
KGU	Marion A. Mulrony	Honolulu, Hawaii.	833	360	500
KGW	Oregonian Publishing Co.	Portland, Ore.	610	492	500
KGY	St. Martins College	Lacey, Wash.	1250	246	5
KHJ	Times-Mirror Co.	Los Angeles, Calif.	742	404	500

Active Broadcasting Stations February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KHQ	Excelsior Motorcycle & Bicycle Company	Seattle, Wash.	1100	273	100
KJQ	C. O. Gould	Stockton, Calif.	1100	273	5
KJR	Northwest Rad. Ser. Co.	Seattle, Wash.	780	384	50
KJS	Bible Inst. of Los Angeles	Los Angeles, Calif.	1020	294	500
KLDS	Reor. Ch. of Jesus Christ of Latter Day Saints	Independence, Mo.	1120	268	250
KLS	Warner Bros.	Oakland, Calif.	833	360	250
KLX	Tribune Publishing Co.	Oakland, Calif.	588	510	500
KLZ	Reynolds Rad. Co., Inc.	Denver, Colo.	1060	283	250
KMJ	San Joaquin Lt.&Pr. Corp.	Fresno, Calif.	1210	248	50
KMO	Love Electric Co.	Tacoma, Wash.	1200	250	10
KNT	Walter Hemrich	Kukak Bay, Alaska.	1140	263	100
KNX	Los Angeles Eve. Express	Los Angeles, Calif.	890	337	500
KOA	General Electric Co.	Denver, Colo.	930	322	1000
KOB	N. Mex. College of Agri. & Mechanic Arts	State College, N.Mex	860	349	500
KOP	Detroit Police Dept.	Detroit, Michigan	1090	275	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	698	430	500
KPPC	Pasadena Pres. Church	Pasadena, Calif.	1310	229	50
KQV	Double-Day Hill Co.	Pittsburgh, Pa.	1090	275	500
KQW	Charles D. Herrold	San Jose, Calif.	1250	240	50
KRE	Berkeley Daily Gazette	Berkeley, Calif.	1090	275	50
KSAC	Kansas State Agri. College	Manhattan, Kans.	880	341	500
KSD	Post-Dispatch	St. Louis, Mo.	550	545	500
KTHS	New Arlington Hotel Co.	Hot Sprgs., Ark.	800	375	500
KTW	First Presbyterian Church	Seattle, Wasn.	833	360	750
KUO	Examiner Printing Co.	San Francisco, Calif.	1220	246	150
KWG	Portable Wireless Tel. Co.	Stockton, Calif.	833	360	50
KWH	Los Angeles Examiner	Los Angeles, Calif.	833	360	250
KYQ	Electric Shop	Honolulu, Hawaii	1110	270	100
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	560	535	1500
KZKZ	Elec. Supply Co.	Manila, P. I.	1110	270	100
KZM	Preston D. Allen	Oakland, Calif.	833	360	100
KZRQ	Far Eastern Radio, Inc.	Manila, P.I.	1360	220	500
WAAB	Valdemar Jensen	New Orleans, La.	1120	268	100
WAAC	Tulane University	New Orleans, La.	1090	275	100
WAAD	Ohio Mechanics Institute	Cincinnati, Ohio	1160	259	25
WAAF	Chic. Daily Drovers Jour.	Chicago, Ill.	1080	278	200
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAN	University of Missouri	Columbia, Mo.	1180	254	50
WAAW	Omaha Grain Exchange	Omaha, Nebr.	1080	278	500
WABA	Lake Forest University	Lake Forest, Ill.	1320	227	100
WABB	Harrisburg Sport. Gds. Co.	Harrisburg, Pa.	1130	265	10
WABH	Lake Shore Tire Co.	Sandusky, Ohio	1250	240	10
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	100
WABL	Connecticut Agri. College	Storrs, Conn.	1090	275	100
WABM	F. E. Dougherty	Saginaw, Mich.	1150	261	20
WABN	Ott Radio, Inc.	La Crosse, Wis.	1230	244	500
WABO	Lake Ave. Baptist Church	Rochester, N. Y.	1080	278	100
WABQ	Haverford Coll. Rad. Club	Haverford, Pa.	1150	261	50
WABR	Scott High S.(J.W.B.Foley)	Toledo, Ohio	1140	263	50
WABU	Victor Talking MachineCo.	Camden, N. J.	1330	225	50
WABW	The College of Wooster Physics Department	Wooster, Ohio	1450	207	20
WABX	Henry B. Joy...... (near	Mt. Clemens, Mich)	1180	254	50
WABY	John Magaldi, Jr.	Philadelphia, Pa.	1240	242	50
WABZ	Coliseum Pl. Baptist Ch.	New Orleans, La.	1140	263	50
WAFD	Albert B. Parfet Co.	Port Huron, Mich.	1290	233	250
WAHG	A. H. Grebe & Co.	Richmond Hill, N.Y.	950	316	500
WAIT	A. H. Waite & Co.	Talenton, Mass.	1310	229	10
WAMD	Hubbard & Co.	Minneapolis, Minn.	1230	244	100
WBAA	Purdue University	W. Lafayette, Ind.	1100	273	250
WBAN	Wireless Phone Corp.	Paterson, N. J.	1230	244	100

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WBAO	James Millikin University	Decatur, Ill.	1090	275	100
WBAP	Ft. Worth Star Telegram	Fort Worth, Texas	630	476	1000
WBAV	Erner & Hopkins Co.	Columbus, Ohio	1020	294	500
WBAX	John H. Stenger, Jr.	Wilkes Barre, Pa.	1170	256	20
WBBA	Plymouth Congrega. Ch.	Newark, Ohio	1330	225	20
WBBD	Barbey Battery Service	Reading, Pa.	1280	234	50
WBBG	Irving Vermilya	Mattapoisett, Mass.	1210	248	500
WBBH	J. Irving Bell	Port Huron, Mich.	1460	205	50
WBBL	Grace Covenant Church	Richmond, Va.	1310	229	100
WBBM	H. Leslie Atlass	Chicago, Ill.	1330	225	200
WBBP	Petoskey High School	Petoskey, Mich.	1400	214	5–100
WBBR	Peoples Pulpit Ass'n	Rossville, N.Y.	1100	273	500
WBBS	First Baptist Church	New Orleans, La.	1190	252	50
WBBU	Jenks Motor Sales Co.	Monmouth, Ill.	1340	224	10
WBBV	Johnstown Radio Co.	Johnstown, Pa.	1210	248	5
WBBW	Ruffner Junior High Sch.	Norfolk, Va.	1350	222	50
WBBY	Washington Light Infantry Co. B. 118th Inf.	Charleston, S. C.	1120	268	10
WBBZ	Noble B. Watson	Indianapolis, Ind.	1260	238	50
WBCN	Foster & McDonnell	Chicago, Ill.	1130	265	500
WBDC	Baxter Laundry Co.	Grd. Rapids, Mich.	1170	256	50
WBES	Bliss Electrical School	Tacoma, Park, Md.	1350	222	100
WBRE	Baltimore Radio Exchange	Wilkes Barre, Pa.	1300	231	10
WBS	D. W. May, Inc.	Newark, N. J.	833	360	100
WBT	Southern Radio Corp.	Charlotte, N.C.	1090	275	250
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	900	331	1500
WCAD	St. Lawrence University	Canton, N. Y.	1140	263	250
WCAE	Kaufman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCAG	Clyde R. Randall	New Orleans, La.	1120	268	50
WCAH	Entrekin Electric Co.	Columbus, Ohio	1130	265	200
WCAJ	Nebraska Wesleyan Univ.	Univ. Place, Nebr.	1090	275	500
WCAL	St. Olaf College, Physics Department	Northfield, Minn.	890	337	500
WCAO	Sanders & Stayman Co.	Baltimore, Md.	1090	275	50
WCAP	Chesapeake & Potomac Tel. Company	Washington, D.C.	640	469	500
WCAR	Southern Rad. Corporation of Texas	San Antonio, Texas	1140	263	100
WCAT	S. Dak. State Sch. of Mines	Rapid City, S.Dak.	1250	240	50
WCAU	Durham & Co.	Philadelphia, Pa.	1080	278	500
WCAV	J. C. Dice Electric Co.	Little Rock, Ark.	1140	263	10
WCAX	University of Vermont	Burlington, Vt.	1200	250	100
WCAY	The Milwaukee Civic Broadcasting Ass'n, Inc.	Milwaukee, Wis.	1130	265	250
WCAZ	Carthage College	Carthage, Ill.	1220	246	50
WCBA	Chas. W. Heimbach	Allentown, Pa.	1180	254	10
WCBC	Univ. of Michigan	Ann Arbor, Mich.	1310	229	200
WCBD	Wilbur Glenn Voliva	Zion, Ill.	870	345	500
WCBE	Uhalt Bros. Radio Co.	New Orleans, La.	1140	263	5
WCBG	Howard S. Williams	Pascagoula, Miss.	1120	268	10
WCBH	University of Mississippi	Oxford, Miss (near)	1240	242	10
WCBI	Nicell, Duncan & Rush	Bemis, Tenn.	1250	240	150
WCBJ	J. C. Maus	Jennings, La.	1230	244	10
WCBL	Northern Radio Mfg. Co.	Houlton, Me.	1130	265	50
WCBM	Hotel Chateau	Baltimore, Md.	1310	229	50
WCBO	The Radio Shop, Inc.	Memphis, Tenn.	1200	250	20
WCBQ	First Baptist Church	Nashville, Tenn.	1270	236	100
WCBR	Charles H. Messter	Providence, R. I.	1460	205	30
WCBT	Clark Univ.Collegiate Dept	Worcester, Mass.	1260	238	250
WCBU	Arnold Wireless SupplyCo.	Arnold, Pa.	1340	224	50
WCBV	Tullahoma Radio Club	Tullahoma, Tenn.	1190	252	10
WCBW	G. P. Rankin, Jr., & M. Solomon	Macon, Ga.	1330	225	10
WCBY	The Forks Elec. Shop	BuckHillFalls, Pa.	1120	268	10

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WCBZ	Coppotelli Bros. Mus. Hse.	Chicago Hghts., Ill.	1210	248	50
WCCO	Washburn Crosby Co......	Minneapolis, Minn..	720	416	500
WCEE	Charles E. Erbstein........	Elgin, Ill............	1090	275	500
WCK	Stix, Baer & Fuller Co.....	St. Louis, Mo......	1100	273	100
WCM	Tex. Markets & Warehouse Department............	Austin, Texas.......	1120	268	250
WCTS	C. T. Sherer..............	Worcester, Mass....	1120	268	100
WCX	Detroit Free Press.........	Detroit, Mich......	580	517	500
WDAE	Tampa Daily Times.......	Tampa, Fla.........	1100	273	250
WDAF	The Kansas City Star.....	Kansas City, Mo...	820	366	500
WDAG	J. L. Martin..............	Amarillo, Texas....	1140	263	100
WDAH	Trinity Methodist Church.	El Paso, Texas.....	1120	268	50
WDAY	Radio Equipment Corp....	Fargo, N. Dak.....	1230	244	50
WDBC	Kirk, Johnson & Co., Inc..	Lancaster, Pa.......	1160	259	50
WDBD	Herman E. Burns.........	Martinsburg, W. Va.	1180	254	5
WDBE	Gilham-Schoen Elec. Co...	Atlanta, Ga.........	1080	278	100
WDBF	Robert G. Phillips.........	Youngstown, Ohio..	1350	222	50
WDBI	Radio Specialty Co........	St. Petersburg,Fla..	1330	225	20
WDBJ	Richardson-Wayland Elec. Corporation............	Roanoke, Va........	1310	229	50
WDBO	Rollins College, Inc.......	Winter Park, Fla...	1250	240	50
WDBP	Superior State Normal Sch.	Superior, Wis.......	1150	261	50
WDBQ	Morton Radio Supply Co..	Salem, N. J.........	1280	234	50
WDBR	Tremont Temp. Baptist Ch	Boston, Mass.......	1170	256	100
WDBS	The S. M. K. Radio Corp..	Dayton, Ohio......	1090	275	5
WDBT	Taylor's Book Store......	Hattiesburg, Miss...	1270	236	10
WDBW	The Radio Den..........	Columbia, Tenn....	1120	268	20
WDBX	Otto Baur...............	N. Y. City, N.Y....	1290	232	5
WDBY	N. Shore Congrega. Church	Chicago, Ill.........	1160	259	500
WDBZ	Boy Scouts of America....	Kingston, N. Y.....	1290	232	5
WDWF	Dutee W. Flint...........	Cranston, R.I.......	680	441	500
WDM	Grace Ch. of the Covenant.	Washington, D.C...	1280	234	50
WDZ	James L. Bush...........	Tuscola, Ill.........	1080	278	10-100
WEAA	Frank D. Fallian & Police Department............	Flint, Mich.........	1280	234	50
WEAF	American Tel. & Tel. Co...	N. Y. City, N.Y....	610	492	2000
WEAH	Wichita Board of Trade...	Wichita, Kans......	1120	268	50
WEAI	Cornell University........	Ithaca, N. Y........	1180	254	500
WEAJ	Univ. of South Dakota....	Vermillion,S. Dak..	1080	278	100
WEAM	Borough of N. Plainfield..	N. Plainfield, N.J...	1150	261	250
WEAN	The Shepard Company....	Providence, R.I.....	1110	270	100
WEAO	Ohio State University.....	Columbus, Ohio....	1020	294	500
WEAP	Mobile Radio Co., Inc....	Mobile. Ala.........	1140	263	100
WEAR	Goodyear Tire & Rub. Co.	Cleveland, Ohio....	770	389	1000
WEAU	Davidson Bros. Co........	Sioux City, Iowa...	1090	275	100
WEAY	Iris Theatre..............	Houston, Texas....	833	360	500
WEBA	The Electric Shop........	Highland Park, N.J.	1290	232	15
WEBC	Walter Cecil Bridges......	Superior, Wis.......	1240	242	10
WEBD	Elec. Equip. & Service Co..	Anderson, Ind......	1220	246	10
WEBE	Roy W. Waller...........	Cambridge, Ohio...	1280	234	10
WEBH	Edgewater Beach Hotel Co	Chicago, Ill.........	810	370	1000
WEBJ	Third Ave. Railway Co....	N. Y. City, N.Y....	1100	273	500
WEBK	Grand Rapids Radio Co...	Grd. Rapids, Mich..	1240	242	20
WEBL	Radio Corp. of America...	U. S. (Portable)....	1330	225	100
WEBM	Radio Corp. of America...	(Portable) Mobile Station..........	1330	225	100
WEBP	Spanish Fort Amuse. Park	New Orleans, La....	1070	280	50
WEBQ	Tate Radio Co...........	Harrisburg, Ill.....	1330	225	10
WEBR	H. H. Howell............	Buffalo, N.Y.......	1230	244	15
WEBT	The Dayton Co-op Industrial High School.......	Dayton, Ohio......	1170	256	5
WEBW	Beloit College............	Beloit, Wis.........	1120	268	500
WEBX	John E. Cain, Jr..........	Nashville, Tenn.....	1140	263	50
WEBY	Hobart Radio Co.........	Roslindale, Mass...	1330	225	10

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WEBZ	Savannah Radio Corp.	Savannah, Ga.	1280	234	5
WEEI	The Edison Elec. Illum. Co	Boston, Mass.	630	476	500
WEMC	Emmanuel Missionary Col.	Berrien Sprgs., Mich.	1050	286	500
WEW	St. Louis University	St. Louis, Mo.	1210	248	100
WFAA	Dallas News&Dallas Jour.	Dallas, Texas	630	476	500
WFAM	Times Publishing Co.	St. Cloud, Minn.	1100	273	10
WFAV	University of Nebraska	Lincoln, Nebr.	1090	275	250
WFBB	Eureka College	Eureka, Ill.	1250	240	100
WFBC	First Baptist Church	Knoxville, Tenn.	1200	250	50
WFBD	Gethsemane Baptist Ch.	Philadelphia, Pa.	1280	234	5
WFBE	John Van DeWalle	Seymour, Ind.	1330	225	20
WFBG	Wm. F. Gable Co.	Altoona, Pa.	1080	278	100
WFBH	Concourse Radio Corp.	N. Y. City, N.Y.	1100	273	500
WFBI	Galvin Radio Supply Co.	Camden, N. J.	1270	236	100
WFBJ	St. John's University	Collegeville, Minn.	1270	236	50
WFBK	Dartmouth College, Wilder Laboratory	Hanover, N. H.	1170	256	100
WFBL	Onondaga Hotel Co.	Syracuse, N.Y.	1190	252	100
WFBM	Merchants Heat&Lgt. Co.	Indianapolis, Ind.	1120	268	250
WFBN	Rad. Sales&Service Co.	Bridgewater, Mass.	1330	225	200
WFBQ	Wynne Radio Co.	Raleigh, N. C.	1190	252	50
WFBR	Fifth Inf. Maryland N. G.	Baltimore, Md.	1180	254	100
WFBT	Gloucester Co.Civic League	Pitman. N.J.	1300	231	50
WFBY	Signal Officer	Ft. Ben.HarrisonInd	1160	259	100
WFBZ	Knox College	Galesburg, Ill.	1180	254	10
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGAL	Lancaster Electric Supply & Construction Co.	Lancaster, Pa.	1210	248	10
WGAQ	Youree Hotel	Shreveport, La.	1140	263	150
WGAZ	South Bend Tribune	So. Bend, Ind.	1090	275	250
WGBA	Jones Elec.&Rad. Mfg. Co.	Baltimore, Md.	1180	254	50
WGBB	Harry H. Carman	Freeport, N.Y.	1240	244	100
WGBC	First Baptist Church	Memphis, Tenn.	1130	265	10
WGBF	The Finke Furniture Co.	Evansville, Ind.	1380	217	50
WGBG	Breitenbach's Radio Shop.	Thrifton, Va.	1330	225	100
WGBH	Fall River Herald Pub. Co.	Portable in New England States	1430	210	10
WGBI	Frank S. Megargee	Scranton, Pa.	1250	240	10
WGBK	Lawrence W. Campbell	Johnstown, Pa.	1210	248	5
WGBM	Theodore H. Saaty	Providence, R.I.	1280	234	5
WGBN	Hub Radio Shop	La Salle, Ill.	1170	256	10
WGBO	Dr. Roses Artan	San Juan, P.R.	1090	275	10
WGBQ	Stout Institute	Menomonie, Wis.	1280	234	20
WGBS	Gimbel Brothers	N. Y. City, N.Y.	950	316	1000
WGBT	Furman University	Greenville, S. C.	1270	236	15
WGBW	Valley Theatre	Spring Valley, Ill.	1410	213	20
WGBX	University of Maine	Orono, Me.	1190	252	10
WGBY	Progress Sales Co.	New Lebanon, O.	1370	219	30
WGI	American Rad.&Res. Corp.	Medford, Hillside, Mass.	1150	261	100
WGN	Tribune	Chicago, Ill.	810	370	1000
WGR	Federal Tel. Mfg. Co.	Buffalo, N.Y.	940	319	750
WGST	Ga. School of Tech	Atlanta, Ga.	1110	270	500
WGY	General Electric Co.	Schenectady, N.Y.	760	380	1500
WHA	University of Wisconsin	Madison, Wis.	560	535	500
WHAD	Marquette University	Milwaukee, Wis.	1090	275	500
WHAG	University of Cincinnati.	Cincinnati, Ohio	1290	232	100
WHAM	University of Rochester	Rochester, N.Y.	1080	278	100
WHAR	Paramount Rad.&Elec. Co.	Atlantic City, N.J.	1090	275	100
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAV	Wilmington Elec.Spec. Co.	Wilmington, Del.	1130	265	100
WHAZ	Rensselaer Polytech. Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Auto.&Elec. Sch.	Kansas City Mo.	820	336	500

Active Broadcasting Stations February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
WHBA	C. C. Shaffer	Oil City, Pa.	1200	250	20
WHBB	Hebel's Store (J. Hebel)	Stevens Pt., Wis.	1250	240	50
WHBC	Rev. E. P. Graham	Canton, O.	1810	165	10
WHBD	Chas. W. Howard	...Bellefontaine, O.	1350	222	20
WHDI	Wm. H. Dunwoody	Minneapolis, Minn.	1080	278	100
WHK	The Radiovox Co.	Cleveland, Ohio	1100	273	100
WHN	Geo. Schubel	N. Y. City, N.Y.	833	360	500
WHO	Bankers Life Co.	Des Moines, Iowa	570	526	500
WIAD	Howard R. Miller	Philadelphia, Pa.	1200	250	100
WIAK	Journal-Stockman Co.	Omaha, Nebr.	1080	278	250
WIAS	Home Electric Co.	Burlington, Iowa	1180	254	100
WIK	K. & L. Elec. Co.	McKeesport, Pa.	1280	234	100
WIP	Gimbel Brothers	Philadelphia, Pa.	590	508	500
WJAB	American Electric Co.	Lincoln, Nebr.	1310	229	100
WJAD	Frank P. Jackson	Waco, Texas	850	353	500
WJAG	The Norfolk Daily NewsCo	Norfolk, Nebr.	1110	270	250
WJAK	Clifford L. White	Greentown, Ind.	1180	254	50
WJAM	D. M. Perham	Cedar Rapids, Iowa.	1120	268	20
WJAN	Peoria Star Co.	Peoria, Ill.	1100	273	100
WJAR	The Outlet Co.	Providence, R. I.	980	306	500
WJAS	Pittsburgh Radio Sup.Hse.	Pittsburgh, Pa.	1090	275	500
WJAZ	Zenith Radio Corp.	Chicago, Ill.	1120	268	100
WJD	Denison University	Granville, Ohio	1380	217	10
WJJD	Supreme Lodge, L.O.O.M.	Mooseheart, Ill.	990	303	500
WJZ	Radio Corp. of America	N. Y. City, N.Y.	660	454	1000
WJY	Radio Corp. of America	N. Y. City, N.Y.	740	405	1000
WKAA	H. F. Parr	Cedar Rapids, Iowa.	1080	278	50
WKAD	Charles Looff	E. Providence, R.I.	1250	240	20
WKAN	United Battery Serv. Co.	Montgomery, Ala.	1330	225	20
WKAP	Dutee W. Flint	Cranston, R.I.	1280	234	50
WKAQ	Radio Corp. ot P. R.	San Juan, PortoRico	880	341	500
WKAR	Mich. Agri. College	E. Lansing, Mich.	1050	286	500
WKAV	The Laconia Radio Club	Laconia, N.H.	1180	254	50
WKY	W K Y Radio Shop	OklahomaCity,Okla.	1090	275	100
WLAP	W. V. Jordan	Louisville, Ky.	1090	275	20
WLAX	Greencastle Comm. Broad-casting Station	Greencastle, Ind.	1300	231	10
WLB	University of Minnesota	Minneapolis, Minn.	1080	278	5
WLBL	Wisconsin Dept.of Markets	Stevens Pt., Wis.	1080	278	500
WLIT	Lit Brothers	Philadelphia, Pa.	760	395	500
WLS	Sears, Roebuck & Co.	Chicago, Ill.	870	345	500
WLW	Crosley Radio Corp.	Cincinnati, Ohio	710	422	1500
WMAC	Clive B. Meredith	Cazenovia, N. Y.	1090	275	100
WMAF	Round Hills Radio Corp.	S.Dartmouth, Mass.	833	360	100-500
WMAH	General Supply Co.	Lincoln, Nebr.	1180	254	100
WMAK	Norton Laboratories	Lockport, N.Y.	1130	265	500
WMAN	First Baptist Church	Columbus, Ohio	1080	278	50
WMAQ	Chicago Daily News	Chicago, Ill.	670	448	500
WMAY	Kingshighway Pres. Church	St. Louis, Mo.	1210	248	100
WMAZ	Mercer University	Macon, Ga.	1150	261	100
WMBF	Fleetwood Hotel	Miami Beach, Fla.	780	384	500
WMC	The Commercial Pub. Co.	Memphis, Tenn.	600	500	500
WMH	Ainsworth-Gates Rad. Co.	Cincinnati, Ohio	710	422	750
"	" " " "	" "	920	326	750
WMU	Doubleday-Hill Elec. Co.	Washington, D.C.	1150	261	100
WNAC	Shepard Stores	Boston, Mass.	1070	280	500
WNAD	Univ. of Oklahoma	Norman, Okla.	1180	254	250
WNAL	Omaha Central High Sch.	Omaha, Nebr.	1160	259	20
WNAP	Wittenberg College	Springfield, Ohio	1210	248	100
WNAR	First Christian Church	Butler, Miss.	1300	231	20
WNAT	Lenning Bros. Co.	Philadelphia, Pa.	1200	250	100
WNAX	Dakota Radio App. Co.	Yankton, S.Dak.	1230	244	100
WNJ	Radio Shop of Newark	Newark, N.J.	1290	232	150
WNYC	Dept. of Plant & Structures	N. Y. City, N.Y.	570	526	1000

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WOAC	Page Organ Co.	Lima, Ohio	1130	265	50
WOAF	Tyler Commercial College	Tyler, Texas	833	360	20
WOAI	Southern Equip. Co.	San Antonio, Texas	760	395	500
WOAN	James D. Vaughan	Lawrenceburg, Tenn.	1060	283	500
WOAV	Pennsylvania Nat. Guard	Erie, Pa.	1240	242	50
WOAW	Sovereign Camp, Woodman of the World	Omaha, Nebr.	570	526	1000
WOAX	Franklyn J. Wolff	Trenton, N. J.	1250	240	50
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa	620	484	1500
WOCL	Hotel Jamestown, Inc.	Jamestown, N.Y.	1090	275	15
WOI	Iowa State College	Ames, Iowa	1110	270	500
WOO	John Wanamaker	Philadelphia, Pa.	590	508	500
WOQ	Unity Sch. of Christianity	Kansas City, Mo.	1080	278	500
WOR	L. Bamberger & Co.	Newark, N. J.	740	405	500
WORD	Peoples Pulpit Ass'n	Batavia, Ill.	1080	278	500
WOS	Mo. State Marketing Bur.	Jefferson City, Mo.	680	441	500
WPAJ	Doolittle Radio Corp.	New Haven, Conn.	1120	268	100
WPAK	Agri. College of N. Dak.	Fargo, N. Dak.	1090	275	50
WPAU	Concordia College	Moorhead, Minn.	1160	258	10
WPAZ	Dr. John R. Koch	Charleston, W.Va.	1120	268	10
WPG	Municip. of Atlantic City	Atlantic City, N.J.	1000	300	500
WPSC	Pennsylvania State College	State College, Pa.	1150	261	500
WQAA	Horace A. Beale, Jr.	Parkesburg, Pa.	1360	220	500
WQAC	Gish Radio Service	Amarillo, Texas	1280	234	100
WQAE	Moore Rad. News Station	Springfield, Vt.	1220	246	50
WQAM	Electrical Equip. Co.	Miami, Fla.	1120	268	100
WQAN	Scranton Times	Scranton, Pa.	1200	250	100
WQAO	Calvary Baptist Church	N. Y. City, N.Y.	833	360	100
WQAS	Prince-Walter Co.	Lowell, Mass.	1190	252	100
WQJ	Calumet Baking PowderCo.	Chicago, Ill.	670	448	500
WRAA	The Rice Institute	Houston, Texas	1170	256	100
WRAF	Radio Club, Inc.	Laport, Ind.	1340	224	15
WRAK	Economy Light Co.	Escanaba, Mich.	1170	256	100
WRAL	Northern States Power Co.	St.Croix Falls, Wis.	1210	248	100
WRAM	Lombard College	Galesburg, Ill.	1230	244	100
WRAN	Black Hawk Elec. Co.	Waterloo, Iowa	1270	236	10
WRAO	St. Louis Rad. Service Co.	St. Louis, Mo.	1320	227	10
WRAV	Antioch College	Yellow Sprgs., Ohio.	1140	263	100
WRAW	Ave. Radio&Electric Shop	Reading, Pa.	1260	238	10
WRAX	Flexon's Garage	Gloucester C., N.J.	1120	268	100
WRBC	Immanuel Lutheran Ch.	Valparaiso, Ind.	1080	278	500
WRC	Radio Corp. of America	Washington, D.C.	640	469	500
WREO	Reo Motor Car Co.	Lansing, Mich.	1050	286	500
WRHF	Wash.Radio Hospital Fund	Washington, D.C.	1170	256	50
WRK	Doron Bros. Elec. Co.	Hamilton, Ohio	1110	270	200
WRL	Union College	Schnectady, N.Y.	833	360	500
WRM	University of Illinois	Urbana, Ill.	1100	273	500
WRR	City of Dallas Police and Fire Signal Department	Dallas, Texas	1150	261	200
WRW	Tarrytown Radio Research	Tarrytown, N.Y.	1100	273	500
WSAB	Southeast Missouri State Teachers College	CapeGirardeau, Mo.	1090	275	100
WSAC	Clemson Agri. College	ClemsonColl., S. C.	890	337	500
WSAD	J. A. Foster Co.	Providence, R.I.	1170	256	100
WSAG	Loren Vanderbeck Davis	St.Petersburg, Fla.	1130	265	500
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	920	326	500
WSAJ	Grove City College	Grove City, Pa.	1310	229	250
WSAN	Allentown Call Pub. Co.	Allentown, Pa.	1310	229	10
WSAP	City Temple Seventh Day Adventist Church	N. Y. City, N.Y.	1140	263	250
WSAR	Doughty & Welch Elec.Co.	Fall River, Mass.	1180	254	100
WSAU	Camp Marienfeld	Chesham, N. H.	1310	229	10
WSAV	Clifford W. Vick Radio Construction Co.	Houston, Texas	833	360	100

Active Broadcasting Stations, February 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WSAX	Chicago Radio Lab........	Chicago, Ill.........	1120	268	20
WSAZ	Chase Electric Shop.......	Pomeroy, Ohio.....	1230	244	50
WSB	Atlanta Journal...........	Atlanta, Ga.........	700	428	750
WSL	J. & M. Electric Co........	Utica, N. Y.........	1100	273	100
WSOE	School of Eng. of Mil......	Milwaukee, Wis....	1220	246	100
WSRF	Harden Sales & Service....	Broadlands, Ill......	1290	232	10
WSRO	Radio Company (Harry W. Fahrlonder)............	Hamilton, Ohio....	1190	252	5
WSUI	State Univ. of Iowa.......	Iowa City, Iowa....	620	484	500
WSY	Alabama Polytechnic Inst.	Auburn, Ala.........	1200	250	500
WTAB	Fall River Daily Herald Co	Fall River, Mass....	1130	265	100
WTAC	Penn Traffic Co...........	Johnstown, Pa......	1430	210	100
WTAF	Louis J. Gallo............	New Orleans, La....	1120	268	10
WTAL	Toledo,Rad.&Elec. Co.....	Toledo, Ohio........	1190	252	10
WTAM	The Willard Stor. Bat. Co.	Cleveland, Ohio....	770	389	1500
WTAP	Cambridge Rad.&Elec. Co.	Cambridge, Ill......	1240	242	50
WTAQ	S. H. Van Gorden & Son..	Osseo, Wis..........	1180	254	100
WTAR	Reliance Elec. Co.........	Norfolk, Va.........	1150	261	100
WTAS	Chas. E. Erbstein.........	Elgin, Ill............	990	300	1000
WTAT	The Edison Elec. Ill. Co. of Boston, Mass...........	Boston, Mass.......	1230	244	100
WTAU	Ruegy Battery&Elec. Co..	Tecumseh, Nebr....	1240	242	10
WTAW	Agri. & Mech. Col. of Tex..	Coll Station, Texas.	1110	270	250
WTAX	Williams Hardware Co....	Streator, Ill.........	1300	231	50
WTAY	Oak Leaves Broadcasting Sta.(Pioneer Pub. Co.)..	Oak Park, Ill........	1200	250	500
WTAZ	Thomas J. McGuire.......	Lambertville, N.J...	1150	261	15
WTG	Kansas State Agri. College.	Manhattan, Kans...	1100	273	50
WTIC	The Travelers Insur. Co..	Hartford, Conn.....	860	349	500
WWAD	Wright & Wright, Inc.....	Philadelphia, Pa....	1200	250	100
WWAE	The Alamo Ball Room....	Joliet, Ill...........	1240	242	500
WWAO	Michigan College of Mines.	Houghton, Mich....	1230	244	250
WWI	Ford Motor Company.....	Dearborn, Mich....	1130	265	250
WWJ	Evening News Ass'n......	Detroit, Mich.......	850	353	500
WWL	Loyola University	New Orleans, La....	1090	275	5

NEW ARRANGEMENT OF BROADCASTING STATIONS BY FREQUENCY

Beginning with this issue we have inaugurated a new idea in the arrangement of our broadcasting station list. We have devoted twice the usual space to the frequency list, in order to add to it a feature suggested by one of our readers.

This addition makes possible the recording of dial settings for all stations received. By virtue of the numerical arrangement of the list the recorded settings will be a valuable guide in estimating the approximate adjustment for stations not previously logged.

We are always glad to receive from our readers helpful hints, such as this one, and will endeavor in each case to adopt the idea if possible. We want to make our list meet the needs of all.

GEOGRAPHICAL LIST OF BROADCASTING STATIONS

February 24, 1925

(See Alphabetical List for details)

Alabama

Auburn........WSY
Mobile.........WEAP
Montgomery...WKAN

Alaska

Anchorage.....KFQD
Juneau.........KFIU
Kukak Bay....KNT

Arizona

Phoenix.......KFAD
Phoenix.......KFCB
Tucson........KFDH

Arkansas

Conway.......KFKQ
KFRJ
Fayetteville....KFMQ
Hot Springs....KTHS
Little Rock....KFMB
WCAV
Pine Bluff.....KFPX

California

Bakersfield....KDZB
Berkeley......KRE
Burlingame....KFNZ
Fresno........KMJ
Hanford.......KFRN
Hillsborough...KFQH
Hollywood.....KFQZ
Hollywood.....KFVF
Hollywood.....KFWB
Holy City.....KFQU
Long Beach....KFON
Los Angeles....KFCL
KFI
KFPQ
KFPR
KFQG
KFSG
KHJ
KJS
KNX
KWH
Oakland.......KFUS
KGO
KLS
KLX
KZM
Pasadena......KPPC
Paso Robles...KFNL
Redlands......KFRP
Richmond.....KFOU
Sacramento....KFBK
San Diego.....KDPT
KDYM
KFBC
San Francisco..KFPV
KFRC
KFUQ
KPO
KUO
San Jose.......KQW
San Leandro...KFUU
Santa Ana.....KFAW
Santa Barbara.KFHJ
Santa Rosa....KFNV
Stanford Univ..KFGH
Stockton......KJQ
KWG
Taft..........KFQC
Upland........KFWC
Whittier.......KFOC

Colorado

Boulder.......KFAJ
Colorado Sprgs.KFQE
KFUM
Denver........KFAF
KFDL
KFEL
KFLE
KFUP
KLZ
KOA
Greeley.......KFKA
Gunnison......KFHA

Connecticut

Hartford......WTIC
New Haven....WPAJ
Storrs........WABL

Delaware

Wilmington....WHAV

District of Columbia

Washington....WCAP
WDM
WMU
WRC
WRHF

Florida

Miami Beach..WMBF
Miami........WQAM
St. Petersburg..WDBI
WSAG
Tampa........WDAE
Winter Park...WDBO

Georgia

Atlanta.......WDBE
WGST
WSB
Macon........WCBW
WMAZ
Savannah......WEBZ

Hawaii

Honolulu......KGU
KYQ

Idaho

Boise.........KFAU
KFDD
Kellogg.......KFEY
Moscow.......KFAN
Wallace.......KFOD

Illinois

Batavia.......WORD
Broadlands....WSRF
Cambridge....WTAP
Carthage......WCAZ
Chicago.......KYW
WAAF
WBBM
WBCN
WDBY
WEBH
WGN
WJAZ
WLS
WMAQ
WSAX
WQJ
Chicago Hghts.WCBZ
Decatur.......WBAO
Elgin.........WCEE
WTAS
Eureka........WFBB
Galesburg.....WFBZ
WRAM
Harrisburg.....WEBQ
Joliet.........WWAE
Lake Forest....WABA
LaSalle........WGBN
Monmouth....WBBU
Mooseheart....WJJD
Oak Park......WTAY
Peoria.........WJAN
Rockford......KFLV
Spring Valley..WGBW
Streator.......WTAX
Tuscola.......WDZ
Urbana........WRM
Zion..........WCBD

Indiana

Anderson......WEBD
Evansville.....WGBF
Ft.B.Harrison..WFBY
Greencastle....WLAX
Greentown.....WJAK
Indianapolis...WBBZ
WFBM
Laporte.......WRAF
Seymour......WFBE
So. Bend......WGAZ
Valparaiso.....WRBC
West Lafayette WBAA

Iowa

Ames.........WOI
Atlantic.......KFLZ
Boone.........KFGQ
Burlington.....WIAS
Cedar Falls....KFJX
Cedar Rapids..KELP
WJAM
WKAA
Davenport.....WOC
Des Moines....WHO
Fort Dodge....KFER
KFJY
Iowa City.....KFQP
WSUI
Lamoni.......KFFV
Le Mars.......KFCY
Marengo......KFOL
Marshalltown..KFJB
Oskaloosa.....KFHL
Sioux City.....KFMR
WEAU
Shenandoah....KFNF
Waterloo......WRAN

Kansas

Lawrence......KFKU
Manhattan....KSAC

Geographical List of Broadcasting Stations, February 24, 1925
(See Alphabetical List for details)

WTG
Milford........KFKB
Wichita........KFOT
WEAH

Kentucky

Louisville......WHAS
WLAP

Louisiana

Alexandria.....KFFY
KFRF
Baton Rouge...KFGC
Jennings.......WCBJ
New Orleans...WAAB
WAAC
WABZ
WBBS
WCAG
WCBE
WEBP
WTAF
WWL
Shreveport.....KFDX
WGAQ

Maine

Bangor........WABI
Houlton.......WCBL
Orono.........WGBX
Portland......KFQN

Maryland

Baltimore.....WCAO
WCBM
WFBR
WGBA
Tacoma Park..WBES

Massachusetts

Boston........WDBR
WEEI
WNAC
WTAT
Bridgewater...WFBN
Fall River.....WSAR
WTAB
Lowell.........WQAS
Mattapoisett...WBBG
Medford, Hill-side.........WGI
Roslindale.....WEBY
So. Dartmouth.WMAF
Springfield.....WBZ
Taunton.......WAIT
Worcester.....WCBT
Worcester.....WCTS

Michigan

Ann Arbor.....WCBC
Berrien Sprgs..KFGZ
WEMC
Dearborn......WWI
Detroit........KOP
WCX
WWJ
E. Lansing.....WKAR
Escanaba......WRAK
Flint..........WEAA
Grand Rapids..WBDC
WEBK
Houghton.....WWAO
Lansing.......WREO
Menominee....KFLB
Mt. Clemens...WABX
Petoskey......WBBP
Port Huron....WAFD
WBBH
Saginaw.......WABM

Minnesota

Breckenridge...KFUJ
Collegeville....WFBJ
Minneapolis....KFDZ
KFEX
KFMT
WAMD
WCCO
WHDI
WLB
Moorhead.....WPAU
Northfield.....KFMX
WCAL
St. Cloud......WFAM
St. Paul.......KFOY
Virginia.......KFUZ

Mississippi

Coldwater.....KFNG
Hattiesburg....WDBT
Oxford........WCBH
Pascagoula....WCBG
(See Iowa)

Missouri

Butler.........WNAR
Cape GirardeauWSAB
Carterville.....KFPW
Columbia......WAAN
Houghton.....KFMW
Independence..KLDS
Jefferson City..WOS
Kansas City...WDAF
WHB
WOQ
Moberly.......KFFP
KFOJ
St. Louis......KFQA
KFUO
KSD
WCK
WEW
WMAY
WRAO
Warrensburg...KFNJ

Montana

Butte.........KFKV
KFLA
KFUY
Havre.........KFBB
Helena........KFCC
KFNY
KFSY

Nebraska

Belden........KFQY
David City....KFOR
Hartington....KFRZ
Hastings......KFKX
Lincoln........KFAB
WFAV
WJAB
WMAH
Norfolk.......WJAG
Oak...........KFEQ
Omaha........KFCZ
KFOX
WAAW
WIAK
WNAL
WOAW
Tecumseh.....WTAU
Univ. Place....WCAJ

Nevada

Sparks........KFFR

New Hampshire

Chesham......WSAU
Hanover.......WFBK
Laconia.......WKAV

New Jersey

Atlantic City...WHAR
WPG
Camden.......WABU
WFBI
Gloucester City.WRAX
Highland Park.WEBA
Lambertville...WTAZ
Newark.......WAAM
WBS
WNJ
WOR
No. Plainfield..WEAM
Paterson......WBAN
Pitman........WFBT
Salem.........WDBQ
Trenton........WOAX

New Mexico

Albuquerque...KFLR
State College...KFRY
KOB

New York

Buffalo........WEBR
WGR
Canton........WCAD
Cazenovia.....WMAC
Freeport.......WGBB
Ithaca.........WEAI
Jamestown....WOCL
Kingston......WDBZ
Lockport......WMAK
New York City.WDBX
WEAF
WEBJ
WFBH
WGBS
WHN
WJY
WJZ
WNYC
WQAO
WSAP
Richmond Hill.WAHG
Rochester.....WABO
WHAM
Rossville......WBBR
Schenectady...WGY
WRL
Syracuse......WFBL
Tarrytown.....WRW
Troy..........WHAZ

Geographical List of Broadcasting Stations, February 24, 1925
(See Alphabetical List for details)

Utica..........WSL

North Carolina

Charlotte......WBT
Raleigh........WFBQ

North Dakota

Devils Lake....KDLR
Fargo..........WDAY
WPAK
Grafton........KFRH
Grand Forks....KFJM
KFRL

Ohio

Bellfontaine....WHBD
Cambridge.....WEBE
Canton........WHBC
Cincinnati.....WAAD
WHAG
WLW
WMH
WSAI
Cleveland.....KDPM
WEAR
WHK
WTAM
Columbus.....WBAV
WCAH
WEAO
WMAN
Dayton.......WDBS
WEBT
Granville......WJD
Hamilton......WRK
WSRO
Lima..........WOAC
Newark........WBBA
New Lebanon..WGBY
Pomeroy......WSAZ
Sandusky......WABH
Springfield.....WNAP
Toledo........WABR
WTAL
Wooster........WABW
Yellow Springs.WRAV
Youngstown...WDBF

Oklahoma

Chickasha.....KFGD
Fort Sill.......KFRM
Norman........WNAD
Oklahoma Cty.KFJF
KFQR
WKY

Oregon

Astoria........KFJI
Corvallis......KFOJ
Portland......KFEC
KFIF
KFJR
KFRQ
KGW

Pennsylvania

Allentown.....WCBA
WSAN
Altoona.......WFBG
Arnold........WCBU
Buck Hill Falls.WCBY
E. Pittsburgh..KDKA
Erie..........WOAV
Grove City....WSAJ
Harrisburg.....WABB
Haverford.....WABQ
Johnstown.....WBBV
WGBK
WTAC
Lancaster......WDBC
WGAL
McKeesport...WIK
Oil City.......WHBA
Parkesburg....WQAA
Philadelphia...WABY
WCAU
WFBD
WFI
WIAD
WIP
WLIT
WNAT
WOO
WWAD
Pittsburgh.....KQV
WCAE
WJAS
Reading.......WBBD
WRAW
Scranton......WGBI
WQAN
State College...WPAB
WPSC
Wilkes Barre...WBAX
WBRE

Philippine Islands

Manila.........KZKZ
KZRQ

Porto Rico

San Juan......WGBO
WKAQ

Rhode Island

Cranston......WDWF
WKAP
E. Providence..WKAD
Providence....WCBR
WEAN
WGBM
WJAR
WSAD

South Carolina

Charelston.....WBBY
Clemson College WSAC
Greenville.....WGBT

South Dakota

Brookings.....KFDY
Rapid City....WCAT
Vermillion.....WEAJ
Yankton......WNAX

Tennessee

Bemis.........WCBI
Columbia......WDBW
Knoxville......WFBC
Lawrenceburg..WOAN
Memphis......WCBO
WGBC
WMC
Nashville......WCBQ
WEBX
Tullahoma.....WCBV

Texas

Amarillo.......WDAG
WQAC
Austin.........KFQM
WCM
Beaumont.....KFDM
Beeville........KFRB
College Station.WTAW
Dallas.........WFAA
WRR
Denison.......KFQT
Dublin........KFPL
El Paso.......WDAH
Fort Worth....KFJZ
KFQB
KFRO
WBAP
Galveston.....KFLX
KFUL
Greenville.....KFPM
Houston.......WEAY
WRAA
WSAV
Orange........KFGX
San Antonio...WCAR
WOAI
San Benito....KFLU
Tyler.........WOAF
Waco.........WJAD

Utah

Ogden.........KFCP
KFUR
Salt Lake City.KYDL
KFOO
KFPH
KFPT
KFUT

Vermont

Burlington.....WCAX
Springfield.....WQAE

Virginia

Norfolk.......WBBW
WTAR
Richmond.....WBBL
Roanoke......WDBJ
Thrifton.......WGBG

Washington

Everett.......KFBL
Lacey.........KGY
North Bend....KFQW
Olympia.......KFRW
Pullman.......KFAE
KFRX
Seattle........KDZE
KFHR
KFOA
KFQX
KHQ
KJR
KTW
Spokane.......KFIO
KFPY
Tacoma.......KFBG
KGB
KMO
Walla Walla...KFCF
Yakima.......KFIQ

Geographical List of Broadcasting Stations, February 24, 1925
(See Alphabetical Lisr for derails)

West Virginia	
Charleston	WPAZ
Martinsburg	WDBD
Wisconsin	
Beloit	WEBW
Fond du Lac	KFIZ
La Crosse	WABN
Madison	WHA
Menomonie	WGBQ
Milwaukee	WCAY
	WHAD
	WSOE
Osseo	WTAQ
St. Croix Falls	WRAL
Stevens Point	WHBB
	WLBL
Superior	WDBP
	WEBC
Wyoming	
Laramie	KFBV
Portable	
U. S. (Portable)	WEBL
Mobile Station	WEBM
Portable in New England States	WGBH
CANADIAN	
Alberta	
Calgary	CFAC
	CFCK
	CFCN
	CFHC
	CHBC
	CHCM
	CJCK
	CKCX
	CKLC
	CNRC
Edmonton	CJCA
	CNRE
British Columbia	
Vancouver	CKCD
	CFCQ
	CFYC
	CJCE
	CKFC
Victoria	CFCL
	CFCT
	CHCE
Nanaimo	CFDC
N. Westminster	CFXC
Manitoba	
Winnipeg	CKY
	CNRW
New Brunswick	
Moncton	CNRA
Ontario	
Hamilton	CFCU
	CHCS
	CKOC
Iroquois Falls	CFCH
Kingston	CFRC
Kitchener	CJCF
London	CFCW
	CFLC
	CJGC
Ottawa	CKCO
	CHXC
	CNRO
Sudbury	CFCR
Thorold	CFKC
Toronto	CFCA
	CHIC
	CHNC
	CJBC
	CJCD
	CJCN
	CJSC
	CKCE
	CNRT
Quebec	
Monto Joli	CJCM
Montreal	CFCF
	CHYC
	CJCL
	CKAC
	CNRM
Quebec	CKCI
Saskatchewan	
Saskatoon	CFQC
	CHUC
	CNRS
Regina	CKCK
	CNRR

BROADCASTING STATIONS OF CANADA

Corrected to January 25, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	The Calgary Herald	Calgary, Alberta	697	430	500
CFCA	Star Pub. & Print Co.	Toronto, Ontario	750	400	1000
CFCF	Marconi Wireless Tel. Co. of Canada	Montreal, Quebec	681	440	500
CFCH	Abitibi Pr. & Paper Co.	Iroquois Falls, Ont.	750	400	250
CFCK	Radio Supply Co., Ltd.	Edmonton, Alberta	731	410	50
CFCL	Centennial Me. Church	Victoria, B.C.	750	400	125
CFCN	W. W. Grant Radio, Ltd.	Calgary, Alberta	681	440	1000
CFCQ	Radio Specialties, Ltd.	Vancouver, B.C.	666	450	5
CFCR	Laurentide Air Ser., Ltd.	Sudbury, Ontario	731	410	50
CFCT	The Victoria City Temple	Victoria, B.C.	731	410	250
CFCU	Jack V. Elliot, Ltd.	Hamilton, Ontario	731	410	5
CFCW	London Radio Co.	London, Ontario	697	430	150
CFDC	Sparks Company	Nanaimo, B.C.	697	430	50
CFHC	Henry Birks & Sons, Ltd.	Calgary, Alta.	681	440	1000
CFKC	D. J. Fendell	Thorold, Ontario	1016	295	75
CFLC	Chas. Guy Hunter	London, Ontario	697	430	50
CFQC	The Electric Shop, Ltd.	Saskatoon, Sask.	750	400	50
CFRC	Queens University	Kingston, Ont.	666	450	500
CFXC	Westminster Trust Co.	N. Westminster, B.C	681	440	20
CFYC	Victor Wentworth Odlum	Vancouver, B.C.	750	400	5
CHBC	The Albertan Pub. Co.	Calgary, Alberta	731	410	125
CHCE	Western Can. Rad. Supply	Victoria, B.C.	750	400	5
CHCM	Riley & McCormmick, Ltd.	Calgary, Alberta	681	440	1000
CHCS	The Hamilton Spectator	Hamilton, Ontario	731	410	125
CHIC	Northern Elec. Co., Ltd.	Hillcrest Park, Toronto, Ontario	857	350	50
CHNC	Toronto Rad. Res. Society	Toronto, Ontario	857	350	50
CHUC	Internat. Bible Students Association	Saskatoon, Sask.	750	400	50
CHXC	J. H. Booth, Jr.	Ottawa, Ont.	690	435	250
CHYC	Northern Elec. Co., Ltd.	Montreal, Quebec	880	341	500
CJBC	Jarvis St. Baptist Church	Toronto, Ont.	961	312	1050
CJCA	The Edmonton Jour., Ltd.	Edmonton, Alberta	666	450	125
CJCD	T. Eaton Co., Ltd.	Toronto, Ontario	731	410	50
CJCE	Sprott-Shaw Radio Co.	Vancouver, B.C.	750	400	50
CJCF	The News Record	Kitchener, Ontario	1016	295	100
CJCK	Radio Corp. of Calgary, Ltd	Calgary, Alta.	950	316	250
CJCL	A. Couture	Montreal, P.Q.	1110	270	5
CJCM	J. L. Phillipe Laundry	Monti Joli, Quebec	961	312	500
CJCN	Simons, Agnew & Co.	Toronto, Ontario	731	410	1000
CJGC	London Free Press Co., Ltd.	London, Ontario	697	430	50
CJSC	The Evening Telegram	Toronto, Ontario	697	430	125
CKAC	La Presse Pub. Co., Ltd.	Montreal, P.Q.	692	425	500
CKCD	Vancouver Daily Province	Vancouver, B.C.	731	410	500
CKCE	Canad. Independent Tel. Co.	Toronto, Ontario	666	450	1000
CKCI	Le "Soleil" Limitée	Quebec, P.Q.	1016	295	50
CKCK	Leader Pub. Co., Ltd	Regina, Sask.	714	420	1000
CKCO	Dr. G. M. Geldert (for Ottawa Radio Ass'n)	Ottawa, Ontario	750	400	50
CKCX	P. Burns & Co., Ltd.	Calgary, Alberta	681	440	1000
CKFC	First Congreg. Church	Vancouver, B.C.	779	385	50
CKLC	Wilkinson Electric Co.	Calgary, Alta.	750	400	50
CKOC	Wentworth Rad. Sup. Co., Ltd.	Hamilton, Ont.	731	410	50
CKY	Manitoba Tel. System	Winnipeg, Manitoba	666	450	500
CNRC	Canadian Natl. Railways	Calgary, Alta.	681	440	1000
CNRE	Canadian Natl. Railways	Edmonton, Alta.	666	450	125
CNRM	Canadian Natl. Railways	Montreal, Que.	880	341	500
CNRO	Canadian Natl. Railways	Ottawa, Ontario	690	435	500
CNRR	Canadian Natl. Railways	Regina, Sask.	714	420	1000
CNRS	Canadian Natl. Railways	Saskatoon, Sask.	750	400	50
CNRT	Canadian Natl. Railways	Toronto, Ontario	750	400	1000
CNRW	Canadian Natl. Railways	Winnipeg, Manitoba	666	450	500
CNRA	Canadian Natl. Railways	Moncton, N.B.	958	313	500

CANADIAN STATIONS BY FREQUENCY

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
666	CFCQ	450	Vancouver, B. C.			
666	CFRC	450	Kingston, Ontario			
666	CJCA	450	Edmonton, Alberta			
666	CKCE	450	Toronto, Ontario			
666	CKY	450	Winnipeg, Manitoba			
666	CNRE	450	Edmonton, Alta.			
666	CNRW	450	Winnipeg, Man.			
681	CFCF	440	Montreal, Quebec			
681	CFCN	440	Calgary, Alberta			
681	CFHC	440	Calgary, Alta.			
681	CFXC	440	New Westminster, B.C.			
681	CHCM	440	Calgary, Alberta			
681	CKCX	440	Calgary, Alberta			
681	CNRC	440	Calgary, Alberta			
690	CHXC	435	Ottawa, Ontario			
690	CNRO	435	Ottawa, Ontario			
692	CKAC	425	Montreal, Que.			
697	CFAC	430	Calgary, Alberta			
697	CFCW	430	London, Ontario			
697	CFDC	430	Manaimo, B.C.			
697	CFLC	430	London, Ontario			
697	CJGC	430	London, Ontario			
697	CJSC	430	Toronto, Ontario			
714	CKCK	420	Regina, Sask.			
714	CNRR	420	Regina, Sask.			
731	CFCK	410	Edmonton, Alberta			
731	CFCR	410	Sudbury, Ontario			
731	CFCT	410	Victoria, B. C.			
731	CFCU	410	Hamilton, Ontario			
731	CHBC	410	Calgary, Alberta			
731	CHCS	410	Hamilton, Ontario			
731	CJCD	410	Toronto, Ontario			
731	CJCN	410	Toronto, Ontario			
731	CKCD	410	Vancouver, B.C.			
731	CKOC	410	Hamilton, Ontario			
750	CFCA	400	Toronto, Ontario			
750	CFCH	400	Iroquois Falls, Ontario			
750	CFCL	400	Victoria, B. C.			
750	CFQC	400	Saskatoon, Sask.			
750	CFYC	400	Vancouver, B. C.			
750	CHCE	400	Victoria, B. C.			
750	CHUC	400	Saskatoon, Sask.			
750	CJCE	400	Vancouver, B. C.			
750	CKCO	400	Ottawa, Ont.			
750	CKLC	400	Calgary, Alta.			
750	CNRS	400	Saskatoon, Sask.			
750	CNRT	400	Toronto, Ontario			
779	CKFC	385	Vancouver, B. C.			
857	CHIC	350	Toronto, Ontario			
857	CHNC	350	Toronto, Ontario			
880	CHYC	341	Montreal, Quebec			
880	CNRM	341	Montreal, Quebec			
950	CJCK	316	Calgary, Alta.			
958	CNRA	313	Moncton, N. B.			
961	CJBC	312	Toronto, Ontario			
961	CJCM	312	Monti Joli, Quebec			
1016	CFKC	295	Thorold, Ontario			
1016	CJCF	295	Kitchener, Ontario			
1016	CKCI	295	Quebec, P. Q.			
1110	CJCL	270	Montreal, P. Q.			

Continued from page 8

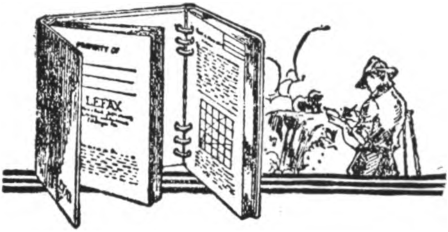
Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1140	WCAR	263	San Antonio, Texas			
1140	WCAV	263	Little Rock, Ark.			
1140	WCBE	263	New Orleans, La.			
1140	WDAG	263	Amarillo, Texas			
1140	WEAP	263	Mobile, Ala.			
1140	WEBX	263	Nashville, Tenn.			
1140	WGAQ	263	Shreveport, La.			
1140	WRAV	263	Yellow Springs, Ohio			
1140	WSAP	263	New York City, N.Y.			
1150	KFAJ	261	Boulder, Colo.			
1150	KFEX	261	Minneapolis, Minn.			
1150	KFJF	261	Oklahoma City, Okla.			
1150	KFMR	261	Sioux City, Iowa			
1150	KFOO	261	Salt Lake City, Utah.			
1150	KFPT	261	Salt Lake City, Utah.			
1150	KFQA	261	St. Louis, Mo.			
1150	KFUT	261	Salt Lake City, Utah.			
1150	WABM	261	Saginaw, Mich.			
1150	WABQ	261	Haverford, Pa.			
1150	WDBP	261	Superior, Wis.			
1150	WEAM	261	N. Plainfield, N.J.			
1150	WGI	261	Medford, Millside, Mass			
1150	WMAZ	261	Macon, Ga.			
1150	WMU	261	Washington, D. C.			
1150	WPSC	261	State College, Pa.			
1150	WRR	261	Dallas, Texas			
1150	WTAR	261	Norfolk, Va.			
1150	WTAZ	261	Lambertville, N. J.			
1160	KFCZ	259	Omaha, Nebr.			
1160	KFDH	259	Tucson, Ariz.			
1160	KFJX	259	Cedar Falls, Iowa			
1160	KFLA	259	Butte, Mont.			
1160	KFUL	259	Galveston, Texas			
1160	WAAD	259	Cincinnati, Ohio			
1160	WDBC	259	Lancaster, Pa.			
1160	WDBY	259	Chicago, Ill.			
1160	WFBY	259	Ft. Ben. Harrison, Ind.			
1160	WNAL	259	Omaha, Nebr.			
1160	WPAU	258	Moorhead, Minn.			
1170	KELP	256	Cedar Rapids, Iowa.			
1170	KFCF	256	Walla Walla, Wash.			
1170	KFIQ	256	Yakima, Wash.			
1170	WBAX	256	Wilkes Barre, Pa.			
1170	WBDC	256	Grand Rapids, Mich.			
1170	WDBR	256	Boston, Mass.			
1170	WEBT	256	Dayton, Ohio			
1170	WFBK	256	Hanover, N. H.			
1170	WGBN	256	La Salle, Ill.			
1170	WRAA	256	Houston, Texas			
1170	WRAK	256	Escanaba, Mich.			
1170	WRHF	256	Washington, D. C.			
1170	WSAD	566	Providence, R. I.			
1180	KFEL	254	Denver, Colo.			
1180	KFJZ	254	Ft. Worth, Texas			
1180	KFLR	254	Albuquerque, N. M.			
1180	KFMB	254	Little Rock, Ark.			
1180	KFNG	254	Coldwater, Miss.			
1180	KFOJ	254	Corvallis, Ore.			
1180	KFOU	254	Richmond, Calif.			
1180	KFQB	254	Fort Worth, Texas			
1180	KFUY	254	Butte, Mont.			
1180	WAAN	254	Columbia, Mo.			
1180	WABX	254	Mt. Clemens, Mich.			
1180	WCBA	254	Allentown, Pa.			

Frequency Kilo cycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1180	WDBD	254	Martinsburg, W. Va....			
1180	WEAI	254	Ithaca, N. Y..........			
1180	WFBR	254	Baltimore, Md.........			
1180	WFBZ	254	Galesburg, Ill.........			
1180	WGBA	254	Baltimore, Md.........			
1180	WIAS	254	Burlington, Iowa......			
1180	WJAK	254	Greentown, Ind........			
1180	WKAV	254	Laconia, N. H.........			
1180	WMAH	254	Lincoln, Nebr.........			
1180	WNAD	254	Norman, Okla..........			
1180	WSAR	254	Fall River, Mass......			
1180	WTAQ	254	Osseo, Wis............			
1190	KFCY	252	Le Mars, Iowa.........			
1190	KFGD	252	Chickasha, Okla.......			
1190	KFHA	252	Gunnison, Colo........			
1190	KFJI	252	Astoria, Ore..........			
1190	KFOY	252	St. Paul, Minn........			
1190	KFPL	252	Dublin, Texas.........			
1190	KFQT	252	Denison, Texas........			
1190	KFUV	252	Springfield, Mo.......			
1190	KFWB	252	Hollywood, Calif......			
1190	WBBS	252	New Orleans La........			
1190	WCBV	252	Tullahoma, Tenn.......			
1190	WFBL	252	Syracuse, N. Y........			
1190	WFBQ	252	Raleigh, N. C.........			
1190	WGBX	252	Orono, Me.............			
1190	WSRO	252	Hamilton, Ohio........			
1190	WTAL	252	Toledo, Ohio..........			
1190	WQAS	252	Lowell, Mass..........			
1200	KDPM	250	Cleveland, Ohio.......			
1200	KFBG	250	Tacoma, Wash..........			
1200	KFDX	250	Shreveport, La........			
1200	KFFV	250	Lamoni, Iowa..........			
1200	KFGX	250	Orange, Texas.........			
1200	KFKQ	250	Conway, Ark...........			
1200	KFRJ	250	Conway, Ark...........			
1200	KGB	250	Tacoma, Wash..........			
1200	KMO	250	Tacoma, Wash..........			
1200	WCAX	250	Burlington, Vt........			
1200	WCBO	250	Memphis, Tenn.........			
1200	WFBC	250	Knoxville, Tenn.......			
1200	WHBA	250	Oil City, Pa..........			
1200	WIAD	250	Philadelphia, Pa......			
1200	WNAT	250	Philadelphia, Pa......			
1200	WQAN	250	Scranton, Pa..........			
1200	WSY	250	Auburn, Ala...........			
1200	WTAY	250	Oak Park, Ill.........			
1200	WWAD	250	Philadelphia, Pa......			
1210	KFCC	248	Helena, Mont..........			
1210	KFEC	248	Portland, Ore.........			
1210	KFIF	248	Portland, Ore.........			
1210	KFJB	248	Marshalltown, Iowa....			
1210	KFLB	248	Menominee, Mich.......			
1210	KFNY	248	Helena, Mont..........			
1210	KFOX	248	Omaha, Nebr...........			
1210	KFRB	248	Beeville, Texas.......			
1210	KFSY	248	Helena, Mont..........			
1300	KFUZ	248	Virginia, Minn........			
1210	KMJ	248	Fresno, Calif.........			
1210	WBBG	248	Mattapoisett, Mass....			
1210	WBBV	248	Johnstown, Pa.........			
1210	WCBZ	248	Chicago Heights, Ill....			
1210	WEW	248	St. Louis, Mo.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1210	WGAL	248	Lancaster, Pa.			
1210	WGBK	248	Johnstown, Pa.			
1210	WMAY	248	St. Louis, Mo.			
1210	WNAP	248	Springfield, Ohio			
1210	WRAL	248	St. Croix Falls, Wis.			
1220	KFJY	246	Fort Dodge, Iowa			
1220	KFOJ	246	Moverly, Mo.			
1220	KFRO	246	Fort Worth, Texas			
1220	KUO	246	San Francisco, Cal.			
1220	WCAZ	246	Carthage, Ill.			
1220	WEBD	246	Anderson, Ind.			
1220	WQAE	246	Springfield, Vt.			
1220	WSOE	246	Milwaukee, Wis.			
1230	KDPT	244	San Diego, Calif.			
1230	WABN	244	La Crosse, Wis.			
1230	WAMD	244	Minneapolis, Minn.			
1230	WBAN	244	Paterson, N. J.			
1230	WCBJ	244	Jennings, La.			
1230	WDAY	244	Fargo, N. Dak.			
1230	WEBR	244	Buffalo, N. Y.			
1230	WNAX	244	Yankton, S. Dak.			
1230	WRAM	244	Galesburg, Ill.			
1230	WSAZ	244	Pomeroy, Ohio			
1230	WTAT	244	Boston, Mass.			
1230	WWAO	244	Houghton, Mich.			
1240	KFPH	242	Salt Lake City, Utah			
1240	KFPM	242	Greenville, Texas			
1240	KFPX	242	Pine Bluff, Ark.			
1240	KFRF	242	Alexandria, La.			
1240	KFUM	242	Colorado Springs, Colo.			
1240	KFUJ	242	Brickenridge, Minn.			
1240	WABY	242	Philadelphia, Pa.			
1240	WCBH	242	Oxford, Miss.			
1240	WEBC	242	Superior, Wis.			
1240	WEBK	242	Grand Rapids, Mich.			
1240	WGBB	242	Freeport, N. Y.			
1240	WOAV	242	Erie, Pa.			
1240	WTAP	242	Cambridge, Ill.			
1240	WWAE	242	Joliet, Ill.			
1240	WTAU	242	Tecumseh, Nebr.			
1250	KDZB	240	Bakersfield, Calif.			
1250	KFAB	240	Lincoln, Nebr.			
1250	KFHL	240	Oskaloosa, Iowa			
1250	KFLX	240	Galveston, Texas			
1250	KFNL	240	Paso Robles, Calif.			
1250	KFQZ	240	Hollywood, Calif.			
1250	KFRL	240	Grand Forks, N. Dak.			
1250	KGY	246	Laccy, Wash.			
1250	KQW	240	San Jose, Calif.			
1250	WABH	240	Sandusky, Ohio			
1250	WABI	240	Bangor, Me.			
1250	WCAT	240	Rapid City, S. Dak.			
1250	WCBI	240	Bemis, Tenn.			
1250	WDBO	240	Winter Park, Fla.			
1250	WFBB	240	Eureka, Ill.			
1250	WGBI	240	Scranton, Pa.			
1250	WHBB	240	Stevens Point, Wis.			
1250	WKAD	240	East Providence, R.I.			
1250	WOAX	240	Trenton, N.J.			
1260	KFCB	238	Phoenix, Ariz.			
1260	KFPG	238	Los Angeles, Calif.			
1260	WBBZ	238	Indianapolis, Ind.			
1260	WCBT	238	Worcester, Mass.			
1260	WRAW	238	Reading, Pa.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1270	KFCL	236	Los Angeles, Calif.			
1270	KFLU	236	San Benito, Texas			
1270	KFOC	236	Whittier, Calif.			
1270	KFPV	236	San Francisco, Calif.			
1270	WCBQ	236	Nashville, Tenn.			
1270	WDBT	236	Hattiesburg, Miss.			
1270	WFBI	236	Camden, N. J.			
1270	WFBJ	236	Collegeville, Minn.			
1270	WGBT	236	Greenville, S. C.			
1270	WRAN	236	Waterloo, Iowa			
1280	KFNJ	234	Warrensburg, Mo.			
1280	KFOL	234	Marengo, Iowa			
1280	KFON	234	Long Beach, Calif.			
1280	KFQU	234	Holy City, Calif.			
1280	KFUP	234	Denver, Colo.			
1280	KFUQ	234	San Francisco, Calif.			
1280	WBBD	234	Reading, Pa.			
1280	WDBQ	234	Salem, N. J.			
1280	WDM	234	Washington, D. C.			
1280	WEAA	234	Flint, Mich.			
1280	WEBE	234	Cambridge, Ohio			
1280	WEBZ	234	Savannah, Ga.			
1280	WFBD	234	Philadelphia, Pa.			
1280	WGBM	234	Providence, R.I.			
1280	WGBQ	234	Menomonie, Wis.			
1280	WIK	234	McKeesport, Pa.			
1280	WKAP	234	Cranston, R. I.			
1280	WQAC	234	Amarillo, Texas			
1290	KFEY	232	Kellogg, Idaho			
1290	KFQX	232	Seattle, Wash.			
1290	KFUS	232	Oakland, Calif.			
1290	KFUW	232	Moberly, Mo.			
1290	WAFD	232	Port Huron, Mich.			
1290	WDBX	232	New York City, N.Y.			
1290	WDBZ	232	Kingston, N.Y.			
1290	WEBA	233	Highland Park, N.J.			
1290	WHAG	232	Cincinnati, Ohio			
1290	WNJ	232	Newark, N. J.			
1290	WSRF	232	Broadlands, Ill.			
1300	KDLR	231	Devils Lake, N. D.			
1300	KFAN	231	Moscow, Idaho			
1300	KFDZ	231	Minneapolis, Minn.			
1300	KFER	231	Fort Dodge, Iowa			
1300	KFNZ	231	Burlingame, Calif.			
1300	KFOT	231	Wichita, Kans.			
1300	KFPR	231	Los Angeles, Calif.			
1300	KFQC	231	Taft, Calif.			
1300	KFQH	231	Hillsbourgh, Calif.			
1300	WBRE	231	Wilkes-Barre, Pa.			
1300	WFBT	231	Pitman, N. J.			
1300	WLAX	231	Greencastle, Ind.			
1300	WNAR	231	Butler, Mo.			
1300	WTAX	231	Streator, Ill.			
1310	KFLV	229	Rockford, Ill.			
1310	KPPC	229	Pasadena, Calif.			
1310	KFQG	229	Los Angeles, Calif.			
1310	WAIT	229	Taunton, Mass.			
1310	WBBL	229	Richmond, Va.			
1310	WCBC	229	Ann Arbor, Mich.			
1310	WCBM	229	Baltimore, Md.			
1310	WDBJ	229	Roanoke, Va.			
1310	WJAB	229	Lincoln, Nebr.			
1310	WSAJ	229	Grove City, Pa.			
1310	WSAN	229	Allentown, Pa.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings
1310	WSAU	229	Chesham, N. H.	
1320	KFNV	227	Santa Rosa, Calif.	
1320	WABA	227	Lake Forest, Ill.	
1320	WRAO	227	St. Louis, Mo.	
1330	KFDL	225	Denver, Colo.	
1330	KFFR	225	Sparks, Nev.	
1330	KFGQ	225	Boone, Iowa	
1330	KFIU	225	Juneau, Alaska	
1330	KFOR	225	David City, Nebr.	
1330	WABU	225	Camden, N. J.	
1330	WBBA	225	Newark, Ohio	
1330	WBBM	225	Chicago, Ill.	
1330	WCBW	225	Macon, Ga.	
1330	WDBI	225	St. Petersburg, Fla.	
1330	WEBL	225	United States (portable)	
1330	WEBM	225	Mobile Station	
1330	WEBQ	225	Harrisburg, Ill.	
1330	WEBY	225	Roslindale, Mass.	
1330	WFBE	225	Seymour, Ind.	
1330	WFBN	225	Bridgewater, Mass.	
1330	WGBG	225	Thrifton, Va.	
1330	WKAN	225	Montgomery, Ala.	
1340	KFBL	224	Everett, Wash.	
1340	KFOD	224	Wallace, Idaho	
1340	KFQE	224	Colorado Springs, Colo.	
1340	KFQP	224	Iowa City, Iowa	
1340	KFRN	224	Hanford, Calif.	
1340	KFUR	224	Ogden, Utah	
1340	KFUU	224	San Leandro, Calif.	
1340	WBBU	224	Monmouth, Ill.	
1340	WCBU	224	Arnold, Pa.	
1340	WRAF	224	Laporte, Ind.	
1350	KFRZ	222	Hartington, Nebr.	
1350	WBBW	222	Norfolk, Va.	
1350	WBES	222	Tacoma Park, Md.	
1350	WDBF	222	Youngstown, Ohio	
1350	WHBD	232	Bellefontaine, Ohio	
1360	KFRW	220	Olympia, Wash.	
1360	KZRQ	220	Manila, P. I.	
1360	WQAA	220	Parkesburg, Pa.	
1370	WGBY	219	New Lebanon, Ohio	
1380	KFRX	217	Pullman, Wash.	
1380	WGBF	217	Evansville, Ind.	
1380	WJD	217	Granville, Ohio	
1390	KFQW	216	No. Bend, Wash.	
1400	WBBP	214	Petoskey, Mich.	
1410	KFRQ	213	Portland, Ore.	
1410	WGBW	213	Spring Valley, Ill.	
1420	KFRP	211	Redlands, Calif.	
1420	KFWC	211	Upland, Calif.	
1430	KFQP	210	Oklahoma City, Okla.	
1430	WGBH	210	Portable in New England States	
1430	WTAC	210	Johnstown, Pa.	
1440	KFVF	208	Hollywood, Calif.	
1450	WABW	207	Wooster, Ohio	
1460	WBBH	205	Port Huron, Mich.	
1460	WCBR	205	Providence, R. I.	
1810	WHBC	254	Canton, Ohio	



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BROADCASTING STATIONS BY FREQUENCY

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
550	KFUO	545	St. Louis. Mo.........			
550	KSD	545	St. Louis, Mo.........			
560	KYW	535	Chicago, Ill...........			
560	WHA	535	Madison, Wis..........			
570	WHO	526	Des Moines, Iowa.....			
570	WNYC	526	New York, N. Y.......			
570	WOAW	526	Omaha, Nebr.........			
580	WCX	517	Detroit, Mich..........			
590	KLX	508	Oakland, Calif.........			
590	WIP	508	Philadelphia, Pa.......			
590	WOO	508	Philadelphia, Pa.......			
600	WMC	500	Memphis, Tenn........			
610	KGW	492	Portland, Ore..........			
610	WEAF	492	New York, N. Y.......			
620	WOC	484	Davenport, Iowa......			
620	WSUI	484	Iowa City, Iowa.......			
630	WBAP	476	Fort Worth, Tex.......			
630	WEEI	476	Boston, Mass..........			
630	WFAA	476	Dallas, Tex............			
640	KFI	469	Los Angeles, Calif.....			
640	WCAP	469	Washington, D. C.....			
640	WRC	469	Washington, D. C.....			
650	WCAE	461	Pittsburgh, Pa.........			
660	KFOA	454	Seattle, Wash..........			
660	KTW	454	Seattle, Wash..........			
660	WJZ	454	New York, N. Y.......			
670	WMAQ	448	Chicago, Ill...........			
670	WQJ	448	Chicago, Ill...........			
680	WDWF	441	Cranston, R. I.........			
680	WOS	441	Jefferson City, Mo.....			
700	KPO	428	San Francisco, Calif...			
700	WSB	428	Atlanta, Ga............			
710	WLW	422	Cincinnati, Ohio.......			
710–920	WKRC	422–326	Cincinnati, Ohio.......			
720	WCCO	416	Minneapolis, Minn.....			
740	KHJ	405	Los Angeles, Calif.....			
740	WJY	405	New York, N. Y.......			
740	WOR	405	Newark, N. J..........			
750	WHAS	400	Louisville, Ky.........			
760	KFRU	395	Bristow, Okla..........			
760	WFI	395	Philadelphia, Pa.......			
760	WOAI	395	San Antonio, Tex......			
760	WLIT	395	Philadelphia, Pa.......			
770	WEAR	389	Cleveland, Ohio.......			
770	WTAM	389	Cleveland, Ohio.......			
780	KJR	384	Seattle, Wash..........			
780	WMBF	384	Miami Beach, Fla......			
790	WGY	380	Schenectady, N. Y.....			
790	WHAZ	380	Troy, N. Y............			
800	KTHS	375	Hot Springs, Ark......			
810	WEBH	370	Chicago, Ill...........			
810	WGN	370	Chicago, Ill...........			
820	WDAF	366	Kansas City, Mo......			
820	WHB	366	Kansas City, Mo......			
830	KGO	361	Oakland, Calif.........			
833	KFHJ	360	Santa Barbara, Calif..			
833	KGU	360	Honolulu, Hawaii......			
833	WHN	360	New York, N. Y.......			
833	WMAF	360	So. Dartmouth, Mass..			
833	WOAF	360	Tyler, Tex.............			
833	WQAO	360	New York, N. Y.......			
833	WRL	360	Schenectady, N. Y.....			
850	WJAD	353	Waco, Tex.............			
850	WWJ	353	Detroit, Mich..........			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
860	KFAE	349	Pullman, Wash........			
860	KOB	349	State College, N. M....			
860	WTIC	349	Hartford, Conn........			
870	WCBD	345	Zion, Ill............			
870	WLS	345	Chicago, Ill..........			
880	KSAC	341	Manhattan, Kans......			
880	WKAQ	341	San Juan, Porto Rico..			
880	WMCA	341	New York, N. Y......			
890	KFMX	337	Northfield, Minn......			
890	KNX	337	Los Angeles, Calif.....			
890	WCAL	337	Northfield, Minn......			
890	WSAC	337	Clemson College, S. C..			
900	KDYL	333	Salt Lake City, Utah...			
900	WBZ	333	Springfield, Mass......			
920	WSAI	326	Cincinnati, Ohio.......			
930	KOA	322	Denver, Colo..........			
940	WGR	319	Buffalo, N. Y..........			
940	WSMB	319	New Orleans, La......			
950	KFDM	316	Beaumont, Tex........			
950	WAHG	316	Richmond Hill, N.Y...			
950	WGBS	316	New York, N. Y......			
970	KDKA	309	E. Pittsburgh, Pa......			
980	WJAR	306	Providence, R. I.......			
990	WJJD	303	Mooseheart. Ill........			
990	WTAS	303	Elgin, Ill.............			
1000	KFMQ	300	Fayetteville, Ark......			
1000	KSL	300	Salt Lake City, Utah...			
1000	WPG	300	Atlantic City, N. J.....			
1020	KJS	294	Los Angeles, Calif.....			
1020	WBAV	294	Columbus, Ohio.......			
1020	WEAO	294	Columbus, Ohio.......			
1040	KFKX	288	Hastings, Nebr........			
1050	KFGZ	286	Berrien Sprgs., Mich...			
1050	WEMC	286	Berrien Sprgs., Mich...			
1050	WKAR	286	E. Lansing, Mich......			
1050	WLAP	286	Louisville, Ky.........			
1050	WREO	286	Lansing, Mich.........			
1060	WOAN	283	Lawrenceburg, Tenn...			
1060	WPAB	283	State College, Pa......			
1070	WNAC	280	Boston, Mass.........			
1080	KFAF	278	Denver, Colo..........			
1080	KFBC	278	San Diego, Calif.......			
1080	KFJM	278	Grand Forks, N. Dak..			
1080	KFSG	278	Los Angeles, Calif.....			
1080	KOP	278	Detroit, Michigan.....			
1080	WAAF	278	Chicago, Ill..........			
1080	WAAW	278	Omaha, Nebr.........			
1080	WABO	278	Rochester, N. Y.......			
1080	WCAU	278	Philadelphia, Pa.......			
1080	WDBE	278	Atlanta, Ga..........			
1080	WDZ	278	Tuscola, Ill..........			
1080	WEAJ	278	Vermillion, S. Dak.....			
1080	WFBG	278	Altoona, Pa..........			
1080	WHAM	278	Rochester, N. Y.......			
1080	WHDI	278	Minneapolis, Minn.....			
1080	WIAK	278	Omaha, Nebr.........			
1080	WKAA	278	Cedar Rapids, Iowa....			
1080	WLB	278	Minneapolis, Minn....			
1080	WLBL	278	Stevens Point, Wis....			
1080	WMAN	278	Columbus, Ohio.......			
1080	WOQ	278	Kansas City, Mo......			
1080	WRBC	278	Valparaiso, Ind.......			
1090	KFAU	275	Boise, Idaho.........			
1090	KFBB	275	Havre, Mont.........			
1090	KFDD	275	Boise, Idaho.........			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1090	KFFY	275	Alexandria, La.			
1090	KFKU	275	Lawrence, Kans.			
1090	KQV	275	Pittsburgh, Pa.			
1090	WAAC	275	New Orleans, La.			
1090	WABL	275	Storrs, Conn.			
1090	WBAK	275	Harrisburg, Pa.			
1090	WBAO	275	Decatur, Ill.			
1090	WBT	275	Charlotte, N. C.			
1090	WCAJ	275	Univ. Place, Nebr.			
1090	WCAO	275	Baltimore, Md.			
1090	WCEE	275	Elgin, Ill.			
1090	WDBS	275	Dayton, Ohio			
1090	WEAU	275	Sioux City, Iowa			
1090	WFAV	275	Lincoln, Nebr.			
1090	WGAZ	275	So. Bend, Ind.			
1090	WGBO	275	San Juan, Porto Rico			
1090	WHAD	275	Milwaukee, Wis.			
1090	WHAR	275	Atlantic City, N. J.			
1090	WJAS	275	Pittsburgh, Pa.			
1090	WKY	275	Oklahoma City, Okla			
1090	WMAC	275	Cazenovia, N. Y.			
1090	WOCL	275	Jamestown, N. Y.			
1090	WORD	275	Batavia, Ill.			
1090	WPAK	275	Fargo, N. Dak.			
1090	WSAB	275	Cape Girardeau, Mo.			
1090	WWL	275	New Orleans, La.			
1100	KFAD	273	Phoenix, Ariz.			
1100	KFDY	273	Brookings, S. Dak.			
1100	KFGH	273	Stanford Univ., Calif.			
1100	KFIZ	273	Fond du Lac, Wis.			
1100	KFKA	273	Greeley, Colo.			
1100	KFKB	273	Milford, Kans.			
1100	KFLZ	273	Atlantic, Iowa			
1100	KFQY	273	Belden, Nebr.			
1100	KHQ	273	Seattle, Wash.			
1100	KJQ	273	Stockton, Calif.			
1100	WAAB	273	New Orleans, La.			
1100	WBAA	273	W. Lafayette, Ind.			
1100	WBBR	273	Rossville, N. Y.			
1100	WCK	273	St. Louis, Mo.			
1100	WDAE	273	Tampa, Fla.			
1110	WEAY	500	Houston, Tex.			
1100	WEBJ	273	New York, N. Y.			
1100	WFAM	273	St. Cloud, Minn.			
1100	WFBH	273	New York, N. Y.			
1100	WHK	273	Cleveland, Ohio			
1100	WIL	273	St. Louis, Mo.			
1100	WRM	273	Urbana, Ill.			
1100	WRW	273	Tarrytown, N. Y.			
1100	WTG	273	Manhattan, Kans.			
1110	KYQ	270	Honolulu, Hawaii			
1110	KZKZ	270	Manila, P. I.			
1110	WDM	270	Washington, D. C.			
1110	WEAN	270	Providence, R. I.			
1110	WGST	270	Atlanta, Ga.			
1110	WJAG	270	Norfolk, Nebr.			
1110	WOI	270	Ames, Iowa			
1110	WOWL	270	New Orleans, La.			
1110	WRK	270	Hamilton, Ohio			
1110	WTAW	270	College Station, Tex.			
1120	KFEQ	268	Oak, Nebr.			
1120	KFGC	268	Baton Rouge, La.			
1120	KFOM	268	Austin, Tex.			
1120	KFPW	268	Carterville, Mo.			
1120	KFRC	268	San Francisco, Calif.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1120	KFRH	268	Grafton, N. Dak			
1120	KLDS	268	Independence, Mo.			
1120	WBBY	268	Charleston, S. C.			
1120	WCAG	268	New Orleans, La.			
1120	WCBG	268	Pascagoula, Miss			
1120	WCM	268	Austin, Tex.			
1120	WCTS	268	Worcester, Mass.			
1120	WDAH	268	El Paso, Tex.			
1120	WDBW	268	Columbia, Tenn.			
1120	WEAH	268	Wichita, Kans.			
1120	WEBW	268	Beloit, Wis.			
1120	WFBM	268	Indianapolis, Ind.			
1120	WJAM	268	Cedar Rapids, Iowa			
1120	WJAZ	268	Chicago, Ill.			
1120	WPAJ	268	New Haven, Conn.			
1120	WPAZ	268	Charleston, W. Va.			
1120	WQAM	268	Miami, Fla.			
1120	WRAX	268	Gloucester, N. J.			
1120	WSAX	268	Chicago, Ill.			
1120	WTAF	268	New Orleans, La.			
1130	KFFP	265	Moberly, Mo.			
1130	KFIO	265	Spokane. Wash.			
1130	KFMW	265	Houghton, Mich.			
1130	KFNF	265	Shenandoah, Iowa			
1130	KFPY	265	Spokane, Wash.			
1130	KFRY	265	State College, N. M.			
1130	KFWD	265	Arkadelphia, Ark.			
1130	KLZ	265	Denver, Colo.			
1130	WABB	265	Harrisburg, Pa.			
1130	WBCN	265	Chicago, Ill.			
1130	WCAH	265	Columbus, Ohio			
1130	WCAY	265	Milwaukee, Wis.			
1130	WCBL	265	Houlton, Maine			
1130	WENR	265	Chicago, Ill.			
1130	WGBC	265	Memphis, Tenn.			
1130	WHAV	265	Wilmington, Del.			
1130	WMAK	265	Lockport, N. Y.			
1130	WSAG	265	St. Petersburg, Fla.			
1130	WTAB	265	Fall River, Mass.			
1130	WWI	265	Dearborn, Mich.			
1140	KFJR	263	Portland, Ore.			
1140	KFMT	263	Minneapolis, Minn.			
1140	KFRM	263	Fort Sill, Okla.			
1140	WAAM	263	Newark, N. J.			
1140	WABR	263	Toledo, Ohio			
1140	WABZ	263	New Orleans, La.			
1140	WCAD	263	Canton, N. Y.			
1140	WCAR	263	San Antonio, Tex.			
1140	WCBE	263	New Orleans, La.			
1140	WDAG	263	Amarillo, Tex.			
1140	WEAP	263	Mobile, Ala.			
1140	WGAQ	263	Shreveport, La.			
1140	WRAV	263	Yellow Springs, Ohio			
1140	WSAP	263	New York, N. Y.			
1150	KFAJ	261	Boulder, Colo.			
1150	KFJF	261	Oklahoma City, Okla.			
1150	KFMR	261	Sioux City, Iowa			
1150	KFOO	261	Salt Lake City, Utah			
1150	KFQA	261	St. Louis, Mo.			
1150	KFUT	261	Salt Lake City, Utah			
1150	KFWA	261	Ogden, Utah			
1150	WABM	261	Saginaw, Mich.			
1150	WABQ	261	Haverford, Pa.			
1150	WARC	261	Medford Hillside, Mass.			

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LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Corrected to April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse E. & M. Co..	E. Pittsburgh, Pa...	970	309	Var.
KDLR	The Radio Elec. Co........	Devils Lake, N.Dak.	1300	231	5
KDPM	Westinghouse E. & M. Co..	Cleveland, Ohio....	1200	250	500
KDYL	Newhouse Hotel..........	Salt Lake City,Utah	900	333	500
KDZB	Frank E. Siefert...........	Bakersfield, Calif....	1430	210	100
KFAB	Nebraska Buick Auto Co..	Lincoln, Nebr......	1250	240	200
KFAD	McArthur Bros. Co........	Phoenix, Ariz.......	1100	273	100
KFAE	State College of Wash.....	Pullman, Wash.....	860	349	500
KFAF	Western Radio Corp.......	Denver, Colo.......	1080	278	500
KFAJ	University of Colorado....	Boulder, Colo......	1150	261	100
KFAN	University of Moscow.....	Moscow, Idaho.....	1300	231	50
KFAU	Boise High School.........	Boise, Idaho........	1090	275	500
KFAW	The Radio Den...........	Santa Ana, Calif....	1400	214	10
KFBB	F. A. Buttrey & Co.......	Havre, Mont........	1090	275	50
KFBC	W. K. Asbill..............	San Diego, Calif....	1080	278	5
KFBE	Horn & Wilson's..........	SanLuisObispo,Calif	1390	216	50
KFBG	First Presbyterian Church.	Tacoma, Wash.....	1200	250	50
KFBK	Kimball-Upson Co.........	Sacramento, Calif...	1210	248	100
KFBL	Leese Bros...............	Everett, Wash.....	1340	224	20
KFBU	Bishop N. S. Thomas.....	Laramie, Wyo......	1110	270	50
KFCB	Nielson Radio Supply Co..	Phoenix, Ariz......	1260	238	50
KFCC	The 1st Congreg. Church..	Helena, Mont.......	1210	248	10
KFCF	Frank A. Moore...........	Walla Walla, Wash..	1170	256	100
KFCL	Leslie E. Rice............	Los Angeles, Calif..	1270	236	500
KFCY	Western Union College....	LeMars, Iowa.......	1190	252	50
KFCZ	Omaha Central H. S.......	Omaha, Nebr.......	1160	259	50
KFDD	St. Michael Cathedral.....	Boise, Idaho.......	1090	275	10
KFDH	University of Arizona......	Tucson, Ariz.......	1160	259	50
KFDJ	Oregon Agri. College......	Corvallis, Ore.......	1180	254	50
KFDM	Magnolia Petroleum Co....	Beaumont, Texas...	950	316	500
KFDX	First Baptist Church......	Shreveport, La.....	1200	250	100
KFDY	S. Dak. State College.....	Brookings, S. Dak..	1100	273	100
KFDZ	Harry O. Iverson..........	Minneapolis, Minn..	1300	231	5
KFEC	Meier & Frank Co.........	Portland, Ore.......	1210	248	50
KFEL	Winner Radio Corp........	Denver, Colo.......	1180	254	50
KFEQ	J. L. Scroggin............	Oak, Nebr..........	1120	268	100
KFER	Auto Elec. Service Co.....	Fort Dodge, Iowa..	1300	231	10
KFEY	Bunker Hill & Sullivan Min. & Concentr. Co....	Kellogg, Idaho.....	1290	233	10
KFFP	First Baptist Church......	Moberly, Mo.......	1130	265	50
KFFR	Nevada State Journal.....	Sparks, Neb........	1330	225	10
KFFV	Graceland College.........	Lamoni, Iowa.......	1200	250	100
KFFY	Louisiana College..........	Alexandria, La......	1090	275	50
KFGC	Louisiana State Univ......	Baton Rouge, La...	1120	268	100
KFGD	Okla. College for Women..	Chickasha, Okla....	1190	252	50
KFGH	Leland Stanford Univ.....	Stanford Univ.,Calif	1100	273	500
KFGQ	Crary Hardware Co.......	Boone, Iowa.......	1330	225	10
KFGX	First Presbyterian Church.	Orange, Tex........	1200	250	500
KFHA	Western State Col. of Colo.	Gunnison, Colo.....	1190	252	50
KFHJ	Fallon & Company........	Santa Barbara,Calif.	833	360	100
KFHL	Penn College.............	Oskaloosa, Iowa....	1250	240	10
KFI	Earle C. Anthony, Inc.....	Los Angeles, Calif...	640	469	2000
KFIF	Benson Polytechnic School.	Portland, Ore.......	1210	248	100
KFIO	North Central H. S.......	Spokane, Wash.....	1130	265	50
KFIQ	First Methodist Church...	Yakima, Wash.....	1170	256	100
KFIU	Alaska Elec. Light&Pr. Co.	Juneau, Alaska.....	1330	225	10
KFIZ	Daily Commonwealth & Seifert Radio Corp......	Fond du Lac, Wis..	1100	273	100
KFJB	Marshall Elec. Co.........	Marshalltown, Iowa.	1210	248	10
KFJF	Nation Radio Mfg. Co....	Oklahoma City,Okla	1150	261	225
KFJI	Liberty Theatre..........	Astoria. Ore........	1220	246	10

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
KFJM	Univ. of North Dakota...	Grand Forks, N.Dak	1080	278	100
KFJR	Ralph Schneeloch Co.......	Portland, Ore.......	1140	263	5
KFJX	Iowa State Teachers Col...	Cedar Falls, Iowa..	1160	259	50
KFJY	Tunwall Radio Co.........	Ft. Dodge, Iowa....	1220	246	50
KFJZ	Tex. National Guard, 112th Cavalry, W. E. Branch..	Ft. Worth, Tex.....	1180	254	50
KFKA	Colo. State Teach. College.	Greeley, Colo.......	1100	273	50
KFKB	Brinley-Jones Hosp. Ass'n.	Milford, Kans......	1100	273	500
KFKQ	Conway Radio Labs.......	Conway, Ark........	1200	250	100
KFKU	The Univ. of Kansas......	Lawrence, Kans....	1090	275	500
KFKX	Westinghouse E. & M. Co..	Hastings, Nebr.....	1040	288	1500
KFLB	Signal Electric Mfg. Co...	Menominee, Mich..	1210	248	50
KFLP	Everette M. Foster........	Cedar Rapids, Iowa.	1170	256	20
KFLR	Univ. of New Mexico.....	Albuquerque, N.M..	1180	254	100
KFLU	San Benito Radio Club....	San Benito, Tex....	1270	236	10
KFLV	Swedish Evang. Miss. Chr.	Rockford, Ill........	1310	229	100
KFLX	George Roy Clough........	Galveston, Tex.....	1250	240	10
KFLZ	Atlantic Automobile Co....	Atlantic, Iowa......	1100	273	100
KFMB	Christian Churches of L.R.	Little Rock, Ark....	1180	254	50
KFMQ	Univ. of Arkansas.........	Fayetteville, Ark....	1000	300	500
KFMR	Morningside College......	Sioux City, Iowa....	1150	261	100
KFMT	Dr. Geo. W. Young........	Minneapolis, Minn..	1140	263	100
KFMW	M. G. Sateren.............	Houghton, Mich....	1130	265	50
KFMX	Carleton College..........	Northfield, Minn....	890	337	750
KFNF	Henry Field Seed Co......	Shenandoah, Iowa..	1130	265	500
KFNG	Wooten'sRadio Shop......	Coldwater, Miss....	1180	254	10
KFNJ	Central Mo. State Teachers' College............	Warrensburg, Mo...	1280	234	50
KFNL	Radio Broadcast Ass'n....	Paso Robles, Calif..	1250	240	10
KFNV	L. A. Drake Battery & Radio Supply Shop.......	Santa Rosa, Calif...	1320	227	5
KFNY	Montana Phonograph Co..	Helena, Mont.......	1210	248	50
KFOA	The Rhodes Dept. Store...	Seattle, Wash.......	660	454	500
KFOC	First Christian Church....	Whittier, Calif.....	1270	236	100
KFOJ	Moberly High Sch. Rad. Cl.	Moberly, Mo........	1220	246	10
KFOL	Leslie M. Schalbuch......	Marengo, Iowa.....	1280	234	10
KFON	Echophone Radio Shop....	Long Beach, Calif...	1280	234	100
KFOO	Latter Day Saints Univ....	Salt Lake City, Utah	1150	261	5
KFOR	David City Tire & Elec. Co.	David City, Nebr...	1330	225	20
KFOT	College Hill Radio Club...	Wichita, Kans......	1300	231	50
KFOY	Beacon Radio Service.....	St. Paul, Minn.....	1190	252	50
KFOX	Board of Ed. Tech. High S.	Omaha, Nebr.......	1210	248	100
KFPG	Oliver S. Garretson........	Los Angeles, Calif..	1260	238	100
KFPL	C. C. Baxter..............	Dublin, Tex........	1190	252	15
KFPM	The New Furniture Co....	Greenville, Tex.....	1240	242	10
KFPR	Los Angeles Co., Forestry Department...........	Los Angeles, Calif..	1300	231	500
KFPV	Heintz & Kohlmoos, Inc...	San Francisco, Calif.	1270	236	50
KFPW	St. Johns M. E. Church...	Carterville, Mo.....	1120	268	20
KFPX	First Presbyterian Church.	Pine Bluff, Ark.....	1240	242	100
KFPY	Symons Investment Co....	Spokane, Wash.....	1130	266	100
KFQA	The Principia............	St. Louis, Mo......	1150	261	50
KFQB	The Searchlight Pub. Co..	Fort Worth, Tex...	1180	254	100
KFQC	Kidd Bros. Radio Shop....	Taft, Calif.........	1300	231	100
KFQG	So. Calif. Radio Ass'n.....	Los Angeles, Calif..	1310	229	50
KFQH	Radio Service Co..........	Burlingame, Calif...	1360	220	50
KFQM	Texas Highway Bulletin...	Austin, Tex........	1120	268	100
KFQP	Geo. S. Carson, Jr.........	Iowa City, Iowa....	1340	224	10
KFQR	Walter La Fayette Ellis...	Oklahoma City, Okla	1430	210	50
KFQT	Texas National Guard....	Denison, Tex.......	1190	252	10
KFQU	W. Riker.................	Holy City, Calif....	1280	234	100
KFQW	C. F. Knierim............	No. Bend, Wash....	1390	216	50
KFQY	Farmers State Bank......	Belden, Nebr.......	1100	273	10
KFQZ	Taft Radio Co...........	Hollywood, Calif...	1330	225	250

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFRB	Hall Brothers	Beeville, Tex.	1210	248	250
KFRC	City of Paris Dry Goods Co	San Francisco, Calif.	1120	268	50
KFRF	W. R. Brown	Alexandria, La.	1240	242	10
KFRH	The Radio Shop, Martin I. Monson	Grafton, N. D.	1120	268	10
KFRL	Men's Club of First Pres. Church	Grand Forks, N.Dak	1250	240	10
KFRM	James P. Boland	Fort Sill, Okla.	1140	263	50
KFRN	M. Lawrence Short	Hanford, Calif.	1340	224	5
KFRP	Trinity Episcopal Church	Redlands, Calif.	1420	211	10
KFRQ	Radio Market Service Co.	Portland, Ore.	1410	213	5
KFRU	Etherical Studios	Bristow, Okla.	760	395	500
KFRW	Unit. Churches of Olympia	Olympia, Wash.	1360	220	100
KFRX	J. Gordan Klemgard	Pullman, Wash.	1380	217	10
KFRY	N. Mex. College of Agri.	State College, N. M.	1130	265	50
KFRZ	The Electric Shop	Hartington, Nebr.	1350	222	15
KFSG	Echo Prk. Evangel. Ass'n.	Los Angeles, Calif.	1080	278	500
KFSY	The Van Blaricom Co.	Helena, Mont.	1210	248	10
KFUJ	Hopport Plumb.&Htg. Co.	Breckenridge. Minn.	1240	242	50
KFUL	Thos.Coggan&Bros.Mu.Co.	Galveston, Tex.	1160	259	10
KFUM	W. D. Corley	Colo. Springs, Colo.	1240	242	100
KFUP	Fitzsimons General Hosp.	Denver, Colo.	1280	234	50
KFUR	H. W. Peery & Co. Redfield	Ogden, Utah	1340	224	50
KFUS	Louis L. Sherman	Oakland, Calif.	1290	232	50
KFUT	University of Utah	Salt Lake City, Utah	1150	261	100
KFUU	Colburn Rad. Laboratories	San Leandro, Calif.	1340	224	100
KFUV	G. Pearson Ward	Springfield, Mo.	1190	252	10
KFUW	Earl W. Lewis	Moberly, Mo.	1290	232	10
KFUY	Irvine H. Bouchard	Butte, Mont.	1180	254	5
KFUZ	Y. M. C. A.	Virginia. Minn.	1210	248	10
KFVC	Bonsberg's Music Co.	Camden, Ark.	1240	242	10
KFVD	McWhinnie Electric Co.	San Pedro, Calif.	1460	205	50
KFVE	Film Corp. of America	St. Louis, Mo.	1250	240	500
KFVF	Clarence B. Juneau	Hollywood, Calif.	1440	208	10
KFVG	First Methodist E. Church	Independence, Kans	1270	236	10
KFVH	Whan Radio Shop	Manhattan, Kans.	1370	219	10
KFVI	Headquarters Troop	Houston, Tex.	1210	248	10
KFVO	Concordia Seminary	St. Louis, Mo.	550	545	500
KFWA	Browning Bros. Co.	Ogden, Utah	1150	261	500
KFWB	Warner Bros. Pictures, Inc.	Hollywood, Calif.	1190	252	500
KFWC	L. E. Wall & C. S. Myers	Upland, Calif.	1420	211	10
KFWD	Arkansas Light & PowerCo.	Arkadelphia, Ark.	1130	266	500
KFWF	St. Louis Truth Center	St. Louis, Mo.	1400	214	250
KGB	Tacoma Daily Ledger	Tacoma, Wash.	1200	250	50
KGO	General Electric Co.	Oakland, Calif.	830	361	2000
KGU	Marion A. Mulrony	Honolulu, Hawaii	833	360	500
KGW	Oregonian Publishing Co.	Portland, Ore.	610	492	500
KGY	St. Martins College	Lacey, Wash.	1250	240	5
KHJ	Times-Mirror Co.	Los Angeles, Calif.	740	405	500
KHQ	Excelsior Motorcycle & Bicycle Co.	Seattle, Wash.	1100	273	100
KJBS	Julius Brunton & Sons Co.	San Francisco, Calif.	1270	236	5
KJQ	G. O. Gould	Stockton, Calif.	1100	273	5
KJR	Northwest Radio Serv. Co.	Seattle, Wash.	780	384	1000
KJS	Bible Inst. of Los Angeles	Los Angeles, Calif.	1020	294	750
KLDS	Reor. Ch. of Jesus Christ of Latter Day Saints	Independence, Mo.	1120	268	250
KLS	Warner Bros.	Oakland, Calif.	1240	242	250
KLX	Tribune Publishing Co.	Oakland, Calif.	590	508	500
KLZ	Reynolds Radio Co., Inc.	Denver, Colo.	1130	265	250
KMJ	San Joaquin Lt. & Pr. Corp.	Fresno, Calif.	1280	234	50
KMO	Love Electric Co.	Tacoma, Wash.	1200	250	10
KNX	Los Angeles Eve. Express	Los Angeles, Calif.	890	337	500
KOA	General Electric Co.	Denver, Colo.	930	322	1000

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KOB	N. Mex. College of Agriculture & Mechanic Arts	State College, N. Mex	860	349	750
KOP	Detroit Police Dept.	Detroit, Mich.	1080	278	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	700	428	500
KPPC	Pasadena Presbyterian Ch.	Pasadena, Calif.	1310	229	50
KQV	Double-Day Hill Co.	Pittsburgh, Pa.	1090	275	500
KQW	Charles D. Herrold	San Jose, Calif.	1330	225	50
KRE	Berkeley Daily Gazette	Berkeley, Calif.	1160	259	50
KSAC	Kans. State Agri. College	Manhattan, Kans.	880	341	500
KSD	Post-Dispatch	St. Louis, Mo.	550	545	750
KSL	Rad. Serv. Corp. of Utah	Salt Lake City, Utah	1000	300	1000
KTHS	New Arlington Hotel Co.	Hot Springs, Ark.	800	375	500
KTW	First Presbyterian Church	Seattle, Wash.	660	454	750
KUO	Examiner Printing Co.	San Francisco, Calif.	1220	246	150
KUOM	State Univ. of Montana	Missoula, Mont.	1230	244	250
KWG	Portable Wireless Tele. Co.	Stockton, Calif.	1210	248	50
KYQ	Electric Shop	Honolulu, Hawaii	1110	270	100
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	560	535	1500
KZKZ	Electric Supply Co.	Manila, P. I.	1110	270	100
KZM	Preston D. Allen	Oakland, Calif.	1240	242	100
KZRQ	Far Eastern Radio, Inc.	Manila, P. I.	1360	220	500
WAAB	Valdemar Jensen	New Orleans, La.	1100	273	100
WAAC	Tulane University	New Orleans, La.	1090	275	100
WAAD	Ohio Mechanics Institute	Cincinnati, Ohio	1160	259	25
WAAF	Chic. Daily Drovers Jour.	Chicago, Ill.	1080	278	200
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAW	Omaha Grain Exchange	Omaha, Nebr.	1080	278	500
WABA	Lake Forest University	Lake Forest, Ill.	1320	227	100
WABB	Harrisburg Sport. GoodsCo	Harrisburg, Pa.	1130	265	10
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	100
WABL	Connecticut Agri. College	Storrs, Conn.	1090	275	100
WABM	F. E. Dougherty	Saginaw, Mich.	1150	261	20
WABN	Ott Radio, Inc.	La Crosse, Wis.	1230	244	500
WABO	Lake Ave. Baptist Church	Rochester, N.Y.	1080	278	100
WABQ	Haverford Coll. Radio Club	Haverford, Pa.	1150	261	50
WABR	Scott High School	Toledo, Ohio	1140	263	50
WABU	Victor Talking Machine Co	Camden, N. J.	1330	225	50
WABW	The College of Wooster	Wooster Ohio	1450	207	50
WABX	Henry B. Joy	Mt. Clemens, Mich.	1220	246	500
WABY	John Magaldi, Jr.	Philadelphia, Pa.	1240	242	50
WABZ	Coliseum Place Bap. Ch.	New Orleans, La.	1140	263	50
WADC	Allen T. Simmons	Akron, Ohio	1160	259	100
WAFD	Albert B. Parfet Co.	Port Huron, Mich.	1170	256	250
WAHG	A. H. Grebe & Co.	Richmond Hill, N.Y.	950	316	500
WAIT	A. H. Waite & Co	Taunton, Mass.	1310	229	10
WAMD	Hubbard & Co.	Minneapolis, Minn.	1230	244	100
WARC	Am. Rad. & Res. Corp.	Medford Hillside, Mass.	1150	261	100
WBAA	Purdue University	W. Lafayette, Ind.	1100	273	250
WBAK	Pennsylvania State Police	Harrisburg, Pa.	1090	275	500
WBAN	Wireless Phone Corp.	Paterson, N. J.	1230	244	100
WBAO	James Millikin University	Decatur, Ill.	1090	275	100
WBAP	Ft. Worth Star Telegram	Frot Worth, Tex.	630	476	1000
WBAV	Erner & Hopkins Co.	Columbus, Ohio	1020	294	500
WBAX	John H. Stenger, Jr.	Wilkes Barre, Pa.	1170	256	10
WBBA	Plymouth Congreg. Church	Newark, Ohio	1330	225	20
WBBG	Irving Vermilya	Mattapoisett, Mass.	1210	248	500
WBBH	J. Irving Bell	Port Huron, Mich.	1460	205	50
WBBL	Grace Covenant Church	Richmond, Va.	1310	229	100
WBBM	H. Leslie Atlass	Chicago, Ill.	1330	225	200
WBBP	Petoskey High School	Petoskey, Mich.	1260	238	100
WBBR	Peoples Pulpit Ass'n.	Rossville, N.Y.	1100	273	500
WBBS	First Baptist Church	New Orleans, La.	1190	252	50
WBBU	Jenks Motor Sales Co.	Monmouth, Ill.	1340	224	10

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WBBV	Johnstown Radio Co......	Johnstown, Pa......	1210	248	5
WBBW	Ruffner Junior H. S........	Norfolk, Va........	1350	222	50
WBBY	Washington Light Infantry Co. B, 118th Inf.........	Charleston, S. C....	1120	268	10
WBBZ	Noble B. Watson..........	Indianapolis, Ind...	1260	238	50
WBCN	Foster & McDonnell......	Chicago, Ill.........	1130	265	500
WBDC	Baxter Laundry Co.......	Grand Rapids, Mich	1170	256	50
WBES	Bliss Electrical School.....	Tacoma Park, Md..	1350	222	100
WBOQ	A. H. Grebe & Co., Inc...	Richmond Hill,N.Y.	1270	236	100
WBRE	Baltimore Radio Exchange.	Wilkes Barre, Pa...	1300	231	10
WBS	D. W. May, Inc..........	Newark, N. J.......	1190	252	200
WBT	Southern Radio Corp......	Charlotte, N. C.....	1090	275	250
WBZ	Westinghouse E. & M. Co.	Springfield, Mass...	900	331	1500
WCAD	St. Lawrence University...	Canton, N. Y......	1140	263	250
WCAE	Kaufman & Baer Co......	Pittsburgh, Pa......	650	461	500
WCAG	Clyde R. Randall.........	New Orleans, La...	1120	268	50
WCAH	Entrekin Electric Co......	Columbus, Ohio....	1130	265	200
WCAJ	Nebr. Wesleyan University	Univ. Place, Nebr...	1090	275	500
WCAL	St.Olaf Coll., Physics Dept.	Northfield, Minn...	890	337	500
WCAO	Sanders & Stayman Co....	Baltimore, Md.....	1090	275	250
WCAP	Chesapeake & Potomac Tel. Company..........	Washington, D.C...	640	469	500
WCAR	So. Radio Corp. of Texas..	San Antonio, Tex...	1140	263	100
WCAT	S. D. State Sch. of Mines..	Rapid City, S. Dak.	1250	240	50
WCAU	Durham & Co............	Philadelphia, Pa....	1080	278	500
WCAX	University of Vermont....	Burlington, Vt......	1200	250	100
WCAY	The Milwaukee Civic Broadcasting Ass'n......	Milwaukee, Wis....	1130	265	250
WCAZ	Carthage College.........	Carthage, Ill.......	1220	246	50
WCBA	Chas. W. Heimbach......	Allentown, Pa......	1180	254	10
WCBC	Univ. of Michigan........	Ann Arbor, Mich...	1310	229	200
WCBD	Wilbur Glenn Voliva......	Zion, Ill...........	870	345	1500
WCBE	Uhalt Brothers Radio Co..	New Orleans, La....	1140	263	5
WCBG	Howard S. Williams......	Pascagoula, Miss...	1120	268	10
WCBH	Univ. of Mississippi.......	Oxford, Miss.......	1240	242	10
WCBI	Nicell, Duncan & Rush....	Bemis, Tenn.......	1250	240	150
WCBJ	J. C. Maus..............	Jennings, La.......	1230	244	10
WCBL	Northern Radio Mfg. Co..	Houlton, Me.......	1130	265	50
WCBM	Hotel Chateau...........	Baltimore, Md......	1310	229	50
WCBQ	First Baptist Church......	Nashville, Tenn....	1270	236	50
WCBR	Charles H. Messter.......	Providence, R. I....	1460	205	30
WCBU	Arnold Wireless Supply Co.	Arnold, Pa.........	1360	220	50
WCBZ	Neutrowound Radio Mfg. Co..................	Chicago Heights, Ill.	1380	217	100
WCBY	The Forks Elec. Shop.....	Buck Hill Falls, Pa.	1300	231	20
WCCO	Washburn Crosby Co.....	Minneapolis, Minn..	720	416	1500
WCEE	Charles E. Erbstein.......	Elgin, Ill..........	1090	275	500
WCK	Stix, Baer & Fuller Co.....	St. Louis, Mo......	1100	273	100
WCM	Tex. Markets & Warehouse Department...........	Austin, Tex........	1120	268	250
WCTS	C. T. Shearer Co.........	Worcester, Mass....	1120	268	100
WCUW	Clark Univ...............	Worcester, Mass....	1260	238	250
WCX	Detroit Free Press........	Detroit, Mich......	580	517	500
WDAE	Tampa Daily Times......	Tampa, Fla........	1100	273	250
WDAF	The Kansas City Star.....	Kansas City, Mo...	820	366	500
WDAG	J. L. Martin.............	Amarillo, Texas....	1140	263	100
WDAH	Trinity Methodist Church.	El Paso, Tex.......	1120	268	50
WDAY	Radio Equipment Corp....	Fargo, N. Dak.....	1230	244	50
WDBC	Kirk, Johnson & Co., Inc..	Lancaster, Pa......	1160	259	50
WDBD	Herman E. Burns.........	Martinsburg, W.Va.	1180	254	5
WDBE	Gilham-Schoen Electric Co.	Atlanta, Ga........	1080	278	100
WDBF	Robert G. Phillips........	Youngstown, Ohio..	1350	222	50
WDBJ	Richardson-Wayland Elec. Corporation..........	Roanoke, Va.......	1310	229	50

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WDBK	M. F. Bros Furn. Hdw. & Radio Store	Cleveland, Ohio	1320	227	100
WDBO	Rollins College, Inc.	Winter Park, Fla.	1250	240	50
WDBP	Superior State Normal Sch.	Superior, Wis.	1240	242	50
WDBQ	Morton Radio Supply Co.	Salem, N. J.	1280	234	10
WDBR	Tremont Temple Bap. Ch.	Boston, Mass	1150	261	100
WDBS	The S. M. K. Radio Corp.	Dayton, Ohio	1090	275	5
WDBT	Taylor's Book Store	Hattiesburg, Miss.	1270	236	10
WDBW	The Radio Den	Columbia, Tenn.	1120	268	20
WDBX	Otto Baur	New York City, N.Y	1290	232	50
WDBY	No. Shore Congreg. Church	Chicago, Ill.	1160	259	500
WDBZ	Boy Scouts of America	Kingston, N.Y.	1290	232	5
WDM	Grace Ch. of the Covenant	Washington, D.C.	1110	270	50
WDOD	Chattanooga Rad. Co., Inc.	Chattanooga, Tenn.	1170	256	50
WDWF	Dutee W. Flint	Cranston, R.I.	680	441	500
WDZ	James L. Bush	Tuscola, Ill.	1080	278	10-100
WEAA	Frank D. Fallain	Flint, Mich.	1280	234	50
WEAF	American Tel. & Tel. Co.	New York, N.Y.	610	492	2000
WEAH	Wichita Board of Trade	Wichita, Kans.	1120	268	100
WEAI	Cornell University	Ithaca, N.Y.	1180	254	500
WEAJ	University of So. Dakota	Vermillion, S. Dak.	1080	278	100
WEAM	Borough of N. Plainfield	N. Plainfield, N. J.	1150	261	250
WEAN	The Shepard Company	Providence, R.I.	1110	270	100
WEAO	Ohio State University	Columbus, Ohio	1020	294	500
WEAP	Mobile Radio Co., Inc.	Mobile, Ala.	1140	263	100
WEAR	Goodyear Tire&RubberCo.	Cleveland, Ohio	770	389	1000
WEAU	Davidson Bros. Co.	Sioux City, Iowa	1090	275	100
WEAY	Iris Theatre	Houston, Tex.	1110	270	500
WEBA	The Electric Shop	Highland Park, N.J.	1290	232	15
WEBC	Walter Cecil Bridges	Superior, Wis.	1240	242	10
WEBD	Elec. Equipment&Serv.Co.	Anderson, Ind.	1220	246	10
WEBE	Roy W. Waller	Cambridge, Ohio	1280	234	10
WEBH	Edgewater Beach Hotel Co.	Chicago, Ill.	810	370	1000
WEBJ	Third Ave. Railway Co.	New York, N.Y.	1100	273	500
WEBK	Grand Rapids Radio Co.	Grand Rapids, Mich.	1240	242	20
WEBL	Radior Corp. of America	U.S. Portable	1330	225	100
WEBM	Radio Corp. of America	U.S. Portable	1330	225	100
WEBQ	Tate Radio Co.	Harrisburg, Ill.	1330	225	10
WEBR	H. H. Howell	Buffalo, N.Y.	1230	244	50
WEBT	The Dayton Coop. Ind.H.S.	Dayton, Ohio	1170	256	5
WEBW	Beloit College	Beloit, Wis.	1120	268	500
WEBY	Hobart Radio Co.	Roslindale, Mass.	1330	225	10
WEBZ	Savannah Radio Corp.	Savannah, Ga.	1280	234	50
WEEI	Edison Elec. Illum. Co.	Boston, Mass.	630	476	500
WEMC	Emmanuel Missionary Col.	BerrienSprgs., Mich.	1050	286	500
WENR	All-American Radio Corp.	Chicago, Ill.	1130	265	10
WEW	St. Louis University	St. Louis, Mo.	1210	248	100
WFAA	Dallas News&Dallas Jour.	Dallas, Tex.	630	476	500
WFAM	Times Publishing Co.	St. Cloud, Minn.	1100	273	10
WFAV	University of Nebraska	Lincoln, Nebr.	1090	275	500
WFBB	Eureka College	Eureka, Ill.	1250	240	100
WFBC	First Baptist Church	Knoxville, Tenn.	1200	250	50
WFBD	Gethsemane Baptist Ch.	Philadelphia, Pa.	1280	234	5
WFBE	John Van DeWalle	Seymour, Ind.	1330	225	10
WFBG	Wm. F. Gable Co.	Altoona, Pa.	1080	278	100
WFBH	Concourse Radio Corp.	New York, N.Y.	1100	273	500
WFBI	Galvin Radio Supply Co.	Camden, N. J.	1270	236	100
WFBJ	St. John's University	Collegeville, Minn.	1270	236	50
WFBK	Dartmouth College	Hanover, N.H.	1170	256	100
WFBL	Onondaga Hotel Co.	Syracuse, N.Y.	1190	252	100
WFBM	Merchants Heat&LightCo.	Indianapolis, Ind.	1120	268	250
WFBN	Radio Sales & Service Co.	Bridgewater, Mass.	1330	225	10
WFBQ	Wynne Radio Co.	Raleigh, N. C.	1190	252	50
WFBR	5th Inf. Maryland N. G.	Baltimore, Md.	1180	254	100

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WFBT	Gloucester Co. Civ. League	Pitman, N. J.	1300	231	50
WFBY	Signal Officer	Ft.Ben.Harrison,Ind	1160	259	100
WFBZ	Knox College	Galesburg, Ill.	1180	254	10
WFI	Strawbridge & Clother	Philadelphia, Pa.	760	395	500
WFKB	Francis K. Bridgman	Chicago, Ill.	1380	217	100
WGAL	Lancaster Electric Supply & Construction Co.	Lancaster, Pa.	1210	248	10
WGAQ	Youree Hotel	Shreveport, La.	1140	263	150
WGAZ	South Bend Tribune	So. Bend, Ind.	1090	275	250
WGBA	Jones Elec. & Rad. Mfg. Co	Baltimore, Md.	1180	254	100
WGBB	Harry H. Carman	Freeport, N.Y.	1240	242	100
WGBC	First Baptist Church	Memphis, Tenn.	1130	265	10
WGBF	The Finke Furniture Co.	Evansville, Ind.	1380	217	50
WGBG	Breitenbach's Radio Shop.	Thrifton, Va.	1330	225	10
WGBH	Fall River Herald Pub. Co.	Portable in N. E. States	1430	210	10
WGBI	Frank S. Megargee	Scranton, Pa.	1250	240	10
WGBK	Lawrence W. Campbell	Johnstown, Pa.	1210	248	5
WGBL	Elyria Radio Association	Elyria, Ohio	1320	277	10
WGBM	Theodore H. Saaty	Providence, R. I.	1280	234	5
WGBN	Hub Radio Shop	La Salle, Ill.	1170	256	10
WGBO	Dr. Roses Artan	San Juan, P. R.	1090	275	10
WGBQ	Stout Institute	Menomonie, Wis.	1280	234	20
WGBS	Gimbel Brothers	New York, N.Y.	950	316	1000
WGBT	Furman University	Greenville, S. C.	1270	236	15
WGBW	Valley Theatre	Spring Valley, Ill.	1410	213	20
WGBX	University of Maine	Orono, Me.	1190	252	10
WGBY	The Progress Sales Co.	New Lebanon, Ohio.	1370	219	30
WGN	The Tribune	Chicago, Ill.	810	370	1000
WGR	Federal Tel. Mfg. Co	Buffalo, N.Y.	940	319	750
WGST	Georgia Sch. of Technology	Atlanta, Ga.	1110	270	500
WGY	General Electric Co.	Schenectady, N.Y.	790	380	1500
WHA	University of Wisconsin	Madison, Wis.	560	535	500
WHAD	Marquette University	Milwaukee, Wis.	1090	275	500
WHAG	University of Cincinnati	Cincinnati, Ohio	1290	232	100
WHAM	University of Rochester	Rochester, N.Y.	1080	278	100
WHAP	A. Alvin Simmons	Brooklyn, N.Y.	1250	240	50
WHAR	Paramount Rad.&Elec. Co.	Atlantic City, N.J.	1090	275	100
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAV	Wilmington Elec. Spec. Co.	Wilmington, Del.	1130	265	100
WHAZ	Rensselaer Polytech. Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Auto.&Elec. Sch.	Kansas City, Mo.	820	366	500
WHBA	C. C. Shaffer	Oil City, Pa.	1200	250	20
WHBB	Hebel's Store (John Hebel)	Stevens Point, Wis.	1250	240	50
WHBC	Rev. E. P. Graham	Canton, Ohio	1180	254	10
WHBD	Chas W. Howard	Bellefontaine, Ohio	1350	222	20
WHBF	Beardsley Specialty Co.	Rock Island, Ill.	1350	222	100
WHBG	John S. Skane	Harrisburg, Pa.	1300	231	20
WHBH	Culver Military Academy	Culver, Ind.	1350	222	100
WHBI	Chesaning Electric Co.	Chesaning, Mich.	1320	227	50
WHBJ	Lauer Auto Co.	Ft. Wayne, Ind.	1280	234	10
WHBK	Franklin St. Garage, Inc.	Ellsworth, Me.	1300	231	10
WHBL	James H. Slusser	Logansport, Ind.	1360	220	50
WHBM	C. L. Carroll	Portage, Chicago, Ill.	1290	232	not ex. 30
WHBN	1st Ave. Methodist Church	St. Petersburg, Fla.	1160	259	10
WHBO	Y. M. C. A.	Pawtucket, R. I.	1300	231	50
WHBP	Johnstown Auto. Co.	Johnstown, Pa.	1170	256	10
WHBQ	Men's Fellowship Class of St. John's M. E. Church	Memphis, Tenn.	1290	232	10
WHBR	Scientific Electric&Mfg.Co.	Cincinnati, Ohio.	1390	216	20
WHBS	Edward Wm. Locke	Mechanicsburg, Ohio	1440	208	10
WHBT	Thomas W. Tizzard, Jr.	Downers Grove., Ill.	1450	207	10

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WHBU	B. L. Bing's Sons..........	Anderson, Ind......	1370	219	10
WHBV	Fred Ray's Radio Shop...	Columbus, Ga......	1230	244	20
WHBW	D. R. Kienzle............	Philadelphia, Pa....	1390	216	100
WHBX	J. W. Bowser............	Punxsutawney, Pa..	1410	213	50
WHBY	St. Norbert's College......	West De Pere, Wis.	1200	250	50
WHDI	William H. Dunwoody....	Minneapolis, Minn.	1080	278	500
WHEC	Hickson Electric Co., Inc..	Rochester, N.Y....	1160	259	100
WHK	The Radiovox Co.........	Cleveland, Ohio....	1100	273	100
WHN	Geo. Schubel............	New York, N.Y....	833	360	500
WHO	Bankers Life Co..........	Des Moines, Iowa..	570	526	500
WIAD	Howard R. Miller.........	Philadelphia, Pa....	1200	250	100
WIAK	Journal-Stockman Co.....	Omaha, Nebr.......	1080	278	250
WIAS	Home Electric Co.........	Burlington, Iowa...	1180	254	100
WIBA	The Capital Times-Studio.	Madison, Wis......	1270	236	100
WIBC	L. M. Tate Post No. 39...	St. Petersburg, Fla.	1350	222	100
WIBD	X-L Radio Service........	Joliet, Ill..........	1500	200	50
WIBE	Martinsburg Rad. Brd. Co.	Martinsburg, W.Va.	1430	210	5
WIBF	S. P. Miller Dance Act....	Wheatland, Wis....	1300	231	50
WIBG	St. Paul's P. E. Church...	Elkins Park, Pa....	1350	222	50
WIBO	Nelson Brothers..........	Chicago, Ill.........	1330	225	10
WIL	Benson Radio Co..........	St. Louis, Mo......	1100	273	100
WIP	Gimbel Brothers..........	Philadelphia, Pa....	590	508	500
WJAD	Frank P. Jackson.........	Waco, Tex.........	850	353	500
WJAG	The Norfolk Daily NewsCo	Norfolk, Nebr......	1110	270	250
WJAK	Clifford L. White.........	Greentown, Ind....	1180	254	20
WJAM	D. M. Perham...........	Cedar Rapids, Iowa.	1120	268	20
WJAR	The Outlet Co...........	Providence, R.I.....	980	306	500
WJAS	Pittsburgh Rad. Sup. Hse..	Pittsburgh, Pa.....	1090	275	500
WJAZ	Zenith Radio Corp........	Chicago, Ill........	1120	268	100
WJBC	Hummer Furniture Co....	LaSalle, Ill........	1280	234	100
WJBD	Ashland Broadcasting Co. C. W. Pfefferkorn......	Ashland, Wisc.....	1290	232	100
WJD	Denison University........	Granville, Ohio.....	1380	217	10
WJJD	Supreme Lodge, L.O.O.M.	Mooseheart, Ill.....	990	303	500
WJY	Radio Corp. of America...	New York, N.Y....	740	405	1000
WJZ	Radio Corp. of America...	New York, N.Y....	660	454	1000
WKAA	H. F. Parr...............	Cedar Rapids, Iowa.	1080	278	50
WKAD	Charles Looff............	E. Providence, R.I.	1250	240	20
WKAP	Dutee W. Flint..........	Cranston, R. I.....	1280	234	50
WKAQ	Radio Corp. of Porto Rico.	SanJuan, PortoRico	880	341	500
WKAR	Mich. Agri. College........	E. Lansing, Mich..	1050	286	500
WKAV	The Laconia Radio Club..	Laconia, N.H......	1430	210	50
WKBE	K. & B. Electric Co.......	Webster, Mass....	1300	231	10
WKRC	Kodel Radio Corp.........	Cincinnati, Ohio...	710–920	422–326	1000
WKY	WKY Radio Shop.........	Oklahoma City, Okla	1090	275	100
WLAL	First Christian Church....	Tulsa, Okla........	1200	250	150
WLAP	W. V. Jordan............	Louisville, Ky.....	1090	275	20
WLAX	Greencastle Community... Broadcasting Station...	Greencastle, Ind....	1300	231	10
WLB	University of Minnesota...	Minneapolis, Minn..	1080	278	5
WLBL	Wisconsin Dept. of Mark'ts	Stevens Pt., Wis....	1080	278	500
WLIT	Lit Brothers.............	Philadelphia, Pa....	760	395	500
WLS	Sears, Roebuck & Co.....	Chicago, Ill........	870	345	500
WLW	Crosley Radio Corp.......	Harrison, Ohio.....	710	422	1500
WMAC	Clive B. Meredith.........	Cazenovia, N.Y....	1090	275	100
WMAF	Round Hills Radio Corp...	S. Dartmouth, Mass	833	360	500
WMAK	Norton Laboratories.......	Lockport, N.Y.....	1130	265	500
WMAN	First Baptist Church......	Columbus, Ohio....	1080	278	50
WMAQ	Chicago Daily News......	Chicago, Ill........	670	448	500
WMAY	Kingshighway Pres.Church	St. Louis, Mo......	1210	248	100
WMAZ	Mercer University........	Macon, Ga.........	1150	261	100
WMBB	Trianon Ball Room.......	Chicago, Ill........	1200	250	500
WMBF	Fleetwood Hotel.........	Miami Beach, Fla..	780	384	500
WMC	The Commercial Pub. Co..	Memphis, Tenn....	500	600	500

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
WMCA	Greeley Square Hotel Co..	New York, N.Y....	880	341	500
WMU	Doubleday-Hill Elec. Co...	Washington, D.C...	1150	261	50
WNAB	The Shepard Stores........	Boston, Mass.......	1200	250	100
WNAC	The Shepard Stores........	Boston, Mass.......	1070	280	500
WNAD	Univ. of Oklahoma........	Norman, Okla......	1180	254	250
WNAL	Omaha Central High School	Omaha, Nebr........	1160	259	20
WNAP	Wittenberg College........	Springfield, Ohio...	1210	248	100
WNAR	First Christian Church....	Butler, Mo.........	1300	231	20
WNAT	Lennig Bros. Co...........	Philadelphia, Pa....	1200	250	100
WNAX	Dakota Radio App. Co....	Yankton, S. Dak...	1230	244	100
WNJ	Radio Shop of Newark....	Newark, N. J.......	1290	232	100
WNYC	Dept. of Plant & Structure.	New York, N.Y....	570	526	1000
WOAC	Page Organ Co............	Lima, Ohio.........	1150	261	50
WOAF	Tyler Commercial College.	Tyler, Tex..........	833	360	10
WOAI	Southern Equip. Co........	San Antonio, Tex...	760	395	500
WOAN	James D. Vaughan........	Lawrenceburg, Tenn	1060	283	500
WOAW	Sover. Camp, W. of the W..	Omaha, Nebr.......	570	526	1000
WOAX	Franklyn J. Wolff.........	Trenton, N.J.......	1250	240	50
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa...	620	484	1500
WOCL	Hotel Jamestown, Inc.....	Jamestown, N.Y...	1090	275	15
WODA	James K. O'Dea Rad. & Victrola Shop...........	Paterson, N.J......	1480	203	10
WOI	Iowa State College........	Ames, Iowa.........	1110	270	500
WOO	John Wanamaker..........	Philadelphia, Pa....	590	508	500
WOQ	Unity Sch. of Christianity.	Kansas City, Mo...	1080	278	500
WOR	L. Bamberger & Co........	Newark, N. J.......	740	405	500
WORD	Peoples Pulpit Ass'n.......	Batavia, Ill.........	1090	275	2000
WOS	Mo. State Marketing Bur..	Jefferson City, Mo..	680	441	500
WOWL	Owl Battery Company....	New Orleans, La....	1110	270	100
WPAJ	Doolittle Radio Corp.....	New Haven, Conn..	1120	268	100
WPAK	Agri. College of N. Dak...	Fargo, N. Dak.....	1090	275	50
WPAZ	Dr. John R. Koch.........	Charleston, W. Va..	1120	268	10
WPG	Municipality of Atlantic C.	Atlantic City, N. J..	1000	300	500
WPSC	Pennsylvania State College	State College, Pa...	1150	261	500
WQAA	Horace A. Beale, Jr........	Parkesburg, Pa.....	1360	220	500
WQAC	Gish Radio Service........	Amarillo, Tex.......	1280	234	100
WQAE	Moore Radio News Station	Springfield, Vt......	1220	246	50
WQAM	Electric Equip. Co.........	Miami, Fla.........	1120	268	100
WQAN	Scranton Times...........	Scranton, Pa.......	1200	250	100
WQAO	Calvary Baptist Church...	New York, N.Y....	833	360	100
WQAS	Prince-Walter Co..........	Lowell, Mass......	1190	252	100
WQJ	Calumet Baking Powder Co	Chicago, Ill.........	670	448	500
WRAA	The Rice Institute.........	Houston, Tex.......	1170	256	100
WRAF	Radio Club, Inc...........	Laporte, Ind.......	1340	224	100
WRAK	Economy Light Co........	Escanaba, Mich....	1170	256	100
WRAL	Northern States Power Co.	St. Croix Falls, Wis.	1210	248	100
WRAM	Lombard College..........	Galesburg, Ill......	1230	244	100
WRAN	Black Hawk Elec. Co......	Waterloo, Iowa.....	1270	236	10
WRAV	Antioch College...........	Yellow Sprgs., Ohio.	1140	263	100
WRAW	Ave. Rad. & Electric Shop.	Reading, Pa........	1260	238	10
WRAX	Flexon's Garage..........	Gloucester, N. J....	1120	268	100
WRBC	Immanuel Luther. Church.	Valparaiso, Ind.....	1080	278	500
WRC	Radio Corp. of America...	Washington, D.C...	640	469	500
WREO	Reo Motor Car Co.........	Lansing, Mich......	1050	286	500
WRHF	Wash. Radio Hosp. Fund..	Washington, D.C...	1170	256	50
WRK	Doron Bros. Elec. Co......	Hamilton, Ohio....	1110	270	200
WRL	Union College............	Schenectady, N.Y..	833	360	500
WRM	Univ. of Illinois...........	Urbana, Ill.........	1100	273	500
WRR	City of Dallas Police & Fire Signal Department.....	Dallas, Tex........	1150	261	350
WRW	Tarrytown Rad. Research.	Tarrytown, N.Y....	1100	273	500
WSAB	Southeast Missouri State Teachers College........	Cape Girardeau, Mo.	1090	275	100
WSAC	Clemson Agri. College.....	Clemson Coll., S. C.	890	337	500

Active Broadcasting Stations, April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WSAD	J. A. Foster Co.	Providence, R.I.	1170	256	100
WSAG	Loren Vanderbeck Davis	St. Petersburg, Fla.	1130	265	500
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	920	326	500
WSAJ	Grove City College	Grove City, Pa.	1310	229	250
WSAN	Allentown Call Pub. Co.	Allentown, Pa.	1310	229	50
WSAP	City Temple 7th Day Ad. Church	New York, N.Y.	1140	263	250
WSAR	Doughty & Welch Elec. Co.	Fall River, Mass.	1180	254	100
WSAU	Camp Marienfeld	Cheaham, N. H.	1310	229	10
WSAX	Chicago Radio Club	Chicago, Ill.	1120	268	20
WSAZ	Chase Electric Shop	Pomeroy, Ohio	1230	244	50
WSB	Atlanta Journal	Atlanta, Ga.	700	428	750
WSKC	World's Star Knitting Co.	Bay City, Mich.	1150	261	50
WSL	J. & M. Electric Co.	Utica, N. Y.	1240	242	100
WSMB	Saenger Amusement Co. & Maison Blanche Co.	New Orleans, La.	940	319	500
WSMH	Shattuck Music House	Owosso, Mich.	1250	240	10
WSOE	Sch. of Eng. of Milwaukee	Milwaukee, Wis.	1220	246	100
WSRF	Harden Sales & Service	Broadlands, Ill.	1290	232	10
WSRO	Harry Fahrlander Rad. Co.	Hamilton, Ohio	1190	252	100
WSUI	Iowa University	Iowa City, Iowa	620	484	500
WSY	Alabama Polytechnic Inst.	Auburn, Ala.	1200	250	500
WTAB	Fall River Daily Herald Co	Fall River, Mass.	1130	265	100
WTAC	Penn Traffic Company	Johnstown, Pa.	1430	210	100
WTAF	Louis J. Gallo	New Orleans, La.	1100	273	10
WTAL	Toledo Radio & Elec. Co.	Toledo, Ohio	1190	252	10
WTAM	The Willard Stor. Bat. Co.	Cleveland, Ohio	770	389	1500
WTAP	Cambridge Rad. & Elec.Co	Cambridge, Ill.	1240	242	50
WTAQ	S. H. Van Gorden & Son	Osseo, Wis.	1180	254	200
WTAR	Reliance Elec. Co.	Norfolk, Va.	1150	261	100
WTAS	Chas. E. Erbstein	Elgin, Ill.	990	303	1000
WTAT	The Edison Elec. Illum. Co.	Boston, Mass.	1230	244	100
WTAU	Ruegy Battery & Elec. Co.	Tecumseh, Nebr.	1240	242	10
WTAW	Agri. & Mech. Coll. of Tex.	College Station, Tex.	1110	270	250
WTAX	Williams Hardware Co.	Streator, Ill.	1300	231	50
WTAY	Oak Leaves Broadcast. Sta.	Oak Park, Ill.	1200	250	500
WTAZ	Thomas J. McGuire	Lambertville, N.J.	1150	261	15
WTG	Kansas State Agri. College	Manhattan, Kans.	1100	273	50
WTHS	Flint Senior High School	Flint, Mich.	1370	219	250
WTIC	The Travelers Insur. Co.	Hartford, Conn.	860	349	500
WWAD	Wright & Wright, Inc.	Philadelphia, Pa.	1200	250	100
WWAE	The Alamo Ball Room	Joliet, Ill.	1240	242	500
WWAO	Michigan College of Mines	Houghton, Mich.	1230	244	250
WWJ	Evening News Ass'n	Detroit, Mich.	850	353	500
WWI	Ford Motor Co.	Dearborn, Mich.	1130	265	500
WWL	Loyola University	New Orleans, La.	1090	275	100

GEOGRAPHICAL LIST OF BROADCASTING STATIONS

April 24, 1925

(See Alphabetical List for details)

City	Station
Alabama	
Auburn	WSY
Mobile	WEAP
Alaska	
Juneau	KFIU
Arizona	
Phoenix	KFAD
	KFCB
Tucson	KFDH
Arkansas	
Arkadelphia	KFWD
Camden	KFVC
Conway	KFFQ
Fayetteville	KFMQ
Hot Springs	KTHS
Little Rock	KFMB
Pine Bluff	KFPX
California	
Bakersfield	KDZB
Berkeley	KRE
Burlingame	KFQH
Fresno	KMJ
Hanford	KFRN
Hollywood	KFQZ
	KFVF
	KFWB
Holy City	KFQU
Long Beach	KFON
Los Angeles	KFCL
	KFI
	KFPQ
	KFPR
	KFQG
	KFSG
	KHJ
	KJS
	KNX
Oakland	KFUS
	KGO
	KLS
	KLX
	KZM
Pasadena	KPPC
Paso Robles	KFNL
Redlands	KFRP
Sacramento	KFBK
San Diego	KFBC
San Francisco	KFPV
	KFRC
	KPO
	KUO
San Jose	KQW
San Leandro	KFUU
SanLuisObispo	KFBE
San Pedro	KFVD
Santa Ana	KFAW
Santa Barnara	KFHJ
Santa Rosa	KFNV
Stanford Uiv	KFGH
Stockton	KJQ
	KWG
Taft	KFQC
Upland	KFWC
Whittier	KFOC
Colorado	
Boulder	KFAJ
Colorado Sprgs.	KFUM
Denver	KFAF
	KFEL
	KFUP
	KLZ
	KOA
Greeley	KFKA
Gunnison	KFHA
Connecticut	
Hartford	WTIC
New Haven	WPAJ
Storrs	WABL
Delaware	
Wilmington	WHAV
District of Columbia	
Washington	WCAP
	WDM
	WMU
	WRC
	WRHF
Florida	
Miami Beach	WMBF
	WQAM
St. Petersburg	WHBN
	WIBC
	WSAG
Tampa	WDAE
Winter Park	WDBO
Georgia	
Atlanta	WDBE
	WGST
	WSB
Columbus	WHBV
Macon	WMAZ
Savannah	WEBZ
Hawaii	
Honolulu	KGU
	KYQ
Idaho	
Boise	KFAU
	KFDD
Kellogg	KFEY
Moscow	KFAN
Illinois	
Batavia	WORD
Broadlands	WSRF
Camoridge	WTAP
Carthage	WCAZ
Chiaego	KYW
	WAAF
	WBBM
	WBCN
	WDBY
	WEBH
	WENR
	WFKB
	WGN
	WHBM
	WIBO
	WJAZ
	WLS
	WMAQ
	WMBB
	WSAX
	WQJ
Chicago Hghts.	WCBZ
Decatur	WBAO
Downers Grove	WHBT
Elgin	WCEE
	WTAS
Eureka	WFBB
Galesburg	WFBZ
	WRAM
Harrisburg	WEBQ
Joliet	WIBD
	WWAE
Lake Forest	WABA
La Salle	WGBN
	WJBC
Monmouth	WBBU
Mooseheart	WJJD
Oak Park	WTAY
Rockford	KFLV
Rock Island	WHBF
Spring Valley	WGBW
Streator	WTAX
Tuscola	WDZ
Urbana	WRM
Zion	WCBD
Indiana	
Anderson	WEBD
	WHBU
Culver	WHBH
Evansville	WGBF
Ft. B. Harrison	WFBY
Ft. Wayne	WHBJ
Greencastle	WLAX
Greentown	WJAK
Indianapolis	WBBZ
	WFBM
Laporte	WRAF
Logansport	WHBL
Seymour	WFBE
So. Bend	WGAZ
Valparaiso	WRBC
W. Lafayette	WBAA
Iowa	
Ames	WOI
Atlantic	KFLZ
Boone	KFGQ
Burlington	WIAS
Cedar Falls	KFJX
Cedar Rapids	KELP
	WJAM
	WKAA
Davenport	WOC
Des Moines	WHO
Fort Dodge	KFER
	KFJY
Iowa City	KFQP
	WSUI
Lamoni	KFFV
LeMars	KFCY
Marengo	KFOL
Marshalltown	KFJB
Oskaloosa	KFHL
Shenandoah	KFNF
Sioux City	KFMR
	WEAU
Waterloo	WRAN
Kansas	
Independence	KFVG

Geographical List of Broadcasting Stations, April 24, 1925

(See Alphabetical List for details)

City	Station
Lawrence	KFKU
Manhattan	KSAC
	KFVH
	WTG
Milford	KFKB
Wichita	KFOT
	WEAH
Kentucky	
Louisville	WHAS
	WLAP
Louisiana	
Alexandria	KFFY
	KFRF
Baton Rouge	KFGC
Jennings	WCBJ
New Orleans	WAAB
	WAAC
	WABZ
	WBBS
	WCAG
	WCBE
	WOWL
	WSMB
	WTAF
	WWL
Shreveport	KFDX
	WGAQ
Maine	
Bangor	WABI
Ellsworth	WHBK
Houlton	WCBL
Orono	WGBX
Maryland	
Baltimore	WCAO
	WCBM
	WFBR
	WGBA
Tacoma Park	WBES
Massachusetts	
Boston	WDBR
	WEEI
	WNAB
	WNAC
	WTAT
Bridgewater	WFBN
Fall River	WSAR
	WTAB
Lowell	WQAS
Mattapoisett	WBBG
Medford Hillside	WARC
Roslindale	WEBY
So. Dartmouth	WMAF
Springfield	WBZ
Taunton	WAIT
Webster	WKBE
Worcester	WCTS
	WCUW
Michigan	
Ann Arbor	WCBC
Bay City	WSKC
Berrien Sprgs	KFGZ
	WEMC
Chesaning	WHBI
Dearborn	WWI
Detroit	KOP
	WCX
	WWJ
East Lansing	WKAR
Escanaba	WRAK
Flint	WEAF
	WTHS
Grand Rapids	WBDC
	WEBK
Houghton	WWAO
Lansing	WREO
Menominee	KFLB
Mt. Clemens	WABX
Owossa	WGMH
Petoskey	WBBP
Pt. Huron	WAFD
	WDBH
Saginaw	WABM
Minnesota	
Breckenridge	KFUJ
Collegeville	WFBJ
Minneapolis	KFDZ
	KFMT
	WAMD
	WCCO
	WHDI
	WLB
Northfield	KFMX
	WCAL
St. Cloud	WFAN
St. Paul	KFOY
Virginia	KFUZ
Mississippi	
Coldwater	KFNG
Hattiesburg	WDBT
Oxford	WCBH
Pascagoula	WCBG
Missouri	
Butler	WNAR
Cape Girardeau	WSAB
Carterville	KFPW
Houghton	KFMW
Independence	KLDS
Jefferson City	WOS
Kansas City	WDAF
	WHB
	WOQ
Moberly	KFFP
	KFOJ
St. Louis	KFQA
	KFUO
	KFVE
	KFWF
	KSD
	WCK
	WEW
	WIL
	WMAY
Warrensburg	KFNJ
Montana	
Butte	KFUY
Havre	KFBB
Helena	KFCC
	KFNY
	KFSY
Missoula	KUOM
Nebraska	
Belden	KFQY
David City	KFOR
Hartington	KFRZ
Hastings	KFKX
Lincoln	KFAB
	WFAV
Norfolk	WJAG
Oak	KFEQ
Omaha	KFCZ
	KFOX
	WAAW
	WIAK
	WNAL
	WOAW
Tecumseh	WTAU
Univ. Place	WCAJ
Nevada	
Sparks	KFFR
New Hampshire	
Chesham	WSAU
Hanover	WFBK
Laconia	WKAV
New Jersey	
Atlantic City	WHAR
	WPG
Camden	WABU
	WFBI
Gloucester City	WRAX
Highland Park	WEBA
Lambertville	WTAZ
Newark	WAAM
	WBS
	WNJ
	WOR
N. Plainfield	WEAM
Paterson	WBAN
	WODA
Pitman	WFBT
Salem	WDBQ
Trenton	WOAX
New Mexico	
Albuquerque	KFLR
State College	KFRY
	KOB
New York	
Brooklyn	WHAP
Buffalo	WEBR
	WGR
Canton	WCAD
Casenovia	WMAC
Freeport	WGBB
Ithaca	WEAI
Jamestown	WOCL
Kingston	WDBZ
Lockport	WMAK
New York City	WDBX
	WEAF
	WEBJ
	WFBH
	WGBS
	WHN
	WJY
	WJZ
	WMAC
	WNYC
	WQAO
	WSAP
Richmond Hill	WAHG
	WBOQ
Rochester	WABO

Geographical List of Broadcasting Stations, April 24, 1925
(See Alphabetical List for details)

Rochester.....WHAM
WHEC
Rossville.......WBBR
Schenectady...WGY
WRL
Syracuse.......WFBL
Tarrytown.....WRW
Troy..........WHAZ
Utica..........WSL

North Carolina

Charlotte......WBT
Raleigh........WFBQ

North Dakota

Devils Lake....KDLR
Fargo..........WDAY
WPAK
Grafton........KFRH
Grand Forks...KFJM
KFRL

Ohio

Akron..........WADC
Bellefontaine...WHBD
Cambridge.....WEBE
Canton.........WHBC
Cincinnati.....WAAD
WHAG
WHBR
WLW
WMH
WSAI
Cleveland......KDPM
WDBK
WEAR
WHK
WTAM
Columbus.....WBAV
WCAH
WEAO
WMAN
Dayton........WDBS
WEBT
Elyria..........WGBL
Granville......WJD
Hamilton......WRK
WSRO
Lima...........WOAC
Mechanicsburg.WHBS
Newark........WBBA
New Lebanon..WGBY
Pomeroy......WSAZ
Springfield.....WNAP
Toledo........WABR
WTAL
Wooster.......WABW
Yellow Springs.WRAV
Youngstown...WDBF

Oklahoma

Chickasha.....KFGD
Fort Sill.......KFRM
Norman.......WNAD
Oklahoma City.KFJF
KFQR
WKY
Tulsa..........WLAL

Oregon

Astoria........KFJI
Corvallis......KFOJ
Portland.......KFEC
KFIF
KFJR
KFRQ
KGW

Pennsylvania

Allentown.....WCBA
WSAN
Altoona........WFBG
Arnold.........WCBU
Buck Hill Falls.WCBY
E. Pittsburgh..KDKA
Elkins Park....WIBG
Grove City....WSAJ
Harrisburg.....WABB
WBAK
WHBG
Haverford.....WABQ
Johnstown.....WBBV
WGBK
WHBP
WTAC
Lancaster......WDBC
WGAL
Oil City.......WHBA
Parkesburg....WQAA
Philadelphia...WABY
WCAU
WFBD
WFI
WHBW
WIAD
WIP
WLIT
WNAT
WOO
WWAD
Pittsburgh.....KQV
WCAE
WJAS
Punxsutawney..WHBX
Reading.......WRAW
Scranton......WGBI
WQAN
State College...WPAB
WPSC
Wilkes Barre...WBAX
WBRE

Philippine Islands

Manila........KZKZ
KZRQ

Porto Rico

San Juan......WGBO
WKAQ

Rhode Island

Cranston......WDWF
WKAP
Pawtucket.....WHBO
Providence.....WKAD
WCBR
WEAN
WGBM
WJAR
WSAD

South Carolina

Charleston.....WBBY
Clemson Coll...WSAC
Greenville.....WGBT

South Dakota

Brookings.....KFDY
Rapid City....WCAT
Vermillion.....WEAJ
Yankton.......WNAX

Tennessee

Bemis.........WCBI
Chattanooga...WDOD
Columbia......WDBW
Knoxville......WFBC
Lawrenceburg..WOAN
Memphis......WGBC
WHBQ
WMC
Nashville......WCBQ

Texas

Amarillo.......WDAG
WQAC
Austin........KFQM
WCM
Beaumont.....KFDM
Beeville........KFRB
College Station.WTAW
Dallas.........WFAA
WRR
Denison.......KFQT
Dublin........KFPL
El Paso.......WDAH
Fort Worth....KFJZ
KFQB
WBAP
Galveston.....KFLX
KFUL
Greenville.....KFPM
Houston.......KFVI
WEAY
WRAA
Orange........KFGX
San Antonio...WCAR
WOAI
San Benito....KFLU
Tyler.........WOAF
Waco.........WJAD

Utah

Ogden.........KFUR
KFWA
Salt Lake City.KDYL
KFOO
KFUT
KSL

Vermont

Burlington.....WCAX
Springfield.....WQAE

Virginia

Norfolk.......WBBW
WTAR
Richmond.....WBBL
Roanoke......WDBJ
Thrifton.......WGBG

Washington

Everett........KFBL
Lacey.........KGY
North Bend....KFQW
Olympia.......KFRW
Pullman.......KFAE
KFRX

Geographical List of Broadcasting Stations, April 24, 1925
(See Alphabetical List for details)

Seattle	KFOA
	KHQ
	KJR
	KTW
Spokane	KFIO
	KFPY
Tacoma	KFBG
	KGB
	KMO
Walla Walla	KFCF
Yakima	KFIQ
West Virginia	
Charleston	WPAZ
Martinsburg	WDBD
	WIBE
Wisconsin	
Ashland	WJBD
Beloit	WEBW
Fond du Lac	KFIZ
LaCrosse	WABN
Madison	WHA
	WIBA
Menominie	WGBQ
Milwaukee	WCAY
	WHAD
	WSOE
Osseo	WTAQ
St. Croix Falls	WRAL
Stevens Point	WHBB
	WLBL
Superior	WDBP
Superior	WEBC
West De Pere	WHBY
Wheatland	WIBF
Wyoming	
Laramie	KFBV
Portable	
Mobile Station	WEBM
Portable in New England States	WGBH
U. S. Portable	WEBL
Canada	
(Alberta)	
Calgary	CFAC
	CFCN
	CFHC
	CHBC
	CHCM
	CKCX
	CKLC
	CNRC
Edmonton	CFCK
	CJCA
	CNRE
British Columbia	
Vancouver	CKCD
	CFYC
	CKFC
Victoria	CFCT
N. Westminster	CFXC
Manitoba	
Winnipeg	CKY
	CNRW
New Brunswick	
Moncton	CNRA
Ontario	
Hamilton	CFCU
	CHCS
	CKOC
Iroquois Falls	CFCH
Kingston	CFRC
Kitchener	CJCF
London	CJGC
Ottawa	CKCO
	CHXC
	CNRO
Thorold	CFKC
Toronto	CFCA
	CHIC
	CHNC
	CNRT
Quebec	
Monti Joli	CJCM
Montreal	CFCF
	CHYC
	CJCL
	CKAC
	CNRM
Saskatchewan	
Saskatoon	CFQC
	CHUC
	CNRS
Regina	CKCK
	CNRR

LIGHTNING ARRESTERS

Little attention has been given to this important accessory, except to explain how it functions as a protective device and to impress the public with the necessity of its installation in order that the requirements of the Fire Underwriters be met.

We find that there are over thirty varieties of lightning arresters on the market. Most of these are modifications of two general types, the air-gap and the vacuum gap. The others employ unique principles, the virtues of which are doubtful.

In order to give our readers a thorough survey of the lightning arrester field (as far as effect on reception is concerned) we are now conducting a test of all available types. The manufacturers have displayed a commendable spirit of co-operation in submitting samples for this purpose. We hope to give a report of our findings in the June issue.

BROADCASTING STATIONS OF CANADA

Corrected to April 24, 1925

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	The Calgary Herald......	Calgary, Alta.......	690	435	500
CFCA	Star Pub. & Print. Co.....	Toronto, Ontario...	840	357	500
CFCF	Marconi Wireless Tel. Co. of Canada, Ltd.........	Montreal, Que......	730	411	1500
CFCH	Abitibi Pr. & Paper Co.Ltd.	Iroquois Falls, Ont.	600	500	250
CFCK	Radio Supply Co., Ltd....	Edmonton, Alta....	580	517	100
CFCN	W. W. Grant Radio, Ltd...	Calgary, Alta......	690	435	750
CFCT	The Victoria City Temple.	Victoria, B. C......	910	330	250
CFCU	Jack V. Elliott, Ltd.......	Hamilton, Ont......	880	341	5
CFHC	Henry Birks & Sons, Ltd..	Calgary, Alta......	690	435	750
CFKC	D. J. Fendell.............	Thorold, Ont.......	1210	248	75
CFQC	The Electric Shop, Ltd....	Saskatoon, Sask....	910	330	250
CFQC	The Electric Shop, Ltd....	Saskatoon, Sask....	910	330	250
CFRC	Queen's University........	Kingston, Ont..(new	W-L Pending)		500
CFXC	Westminster Trust Co....	N. Westminster, B.C.	1030	291	20
CFYC	Victor Wentworth Odlum..	Vancouver, B. C....	730	411	100
CHBC	The Albertan Pub. Co.....	Calgary, Alta......	690	435	750
CHCM	Riley & McCormick, Ltd..	Calgary, Alta......	690	435	750
CHCS	The Hamilton Spectator...	Hamilton, Ont......	880	341	100
CHIC	Northern Electric Co., Ltd.	Toronto, Ont.......	840	357	500
CHNC	Toronto Rad. Res. Society.	Toronto, Ont.......	840	357	500
CHUC	Internat. Bible Students Association............	Saskatoon, Sask....	910	330	250
CHXC	J. R. Booth, Jr...........	Ottawa, Ont........	690	435	250
CHYC	Northern Electric Co., Ltd.	Montreal, P. Q.....	730	411	500
CJCA	The Edmonton Jour., Ltd.	Edmonton, Alta....	580	517	500
CJCF	The News Record........	Kitchener, Ont.....	910	330	50
CJCL	A. Couture..............	Montreal, P. Q.....	1110	270	10
CJCM	J. L. P. Landry..........	Mont Joli, P. Q.....	960	312	500
CJGC	London Free Press Ptg. Co.	London, Ont........	910	330	50
CKAC	LaPresse Pub. Co., Ltd....	Montreal, Que......	730	411	1500
CKCD	Vancouver Daily Province.	Vancouver, B. C....	730	411	500
CKCK	Leader Pub. Co., Ltd......	Regina, Sask.......	960	312	1000
CKCO	Dr. G. M. Geldert.........	Ottawa, Ont........	690	435	100
CKCX	P. Burns & Co., Ltd.......	Calgary, Alta......	690	435	750
CKFC	First Congreg. Church....	Vancouver, B. C....	730	411	50
CKLC	Wilkinson Electric Co.....	Calgary, Alta......	690	435	50
CKNC	The Can. Nat'l Carbon Co.	Toronto, Ont.......	840	357	500
CKOC	Wentworth R. S. Co., Ltd.	Hamilton, Ont......	880	341	50
CKY	Manitoba Tel. System....	Winnipeg, Man.....	780	384	500
CNRA	Canadian Natl. Railways..	Moncton, N. B.....	960	312	500
CNRC	Canadian Natl. Railways..	Calgary. Alta.......	690	435	750
CNRE	Canadian Natl. Railways..	Edmonton, Alta....	580	517	500
CNRM	Canadian Natl. Railways..	Montreal. P. Q.....	730	411	500–1500
CNRO	Canadian Natl. Railways..	Ottawa, Ont........	690	435	500
CNRR	Canadian Natl. Railways..	Regina, Sask.......	960	312	1000
CNRS	Canadian Natl. Railways..	Saskatoon, Sask....	910	330	250
CNRT	Canadian Natl. Railways..	Toronto, Ont.......	840	357	500
CNRW	Canadian Natl. Railways..	Winnipeg, Man.....	780	384	500

Stations appearing in our former listing, not included above, have not as yet complied with the requirements of the Dominion and renewed their licenses for this year.

When they resume active operation, we will again include them in our listing.

CANADIAN BROADCASTING STATIONS BY FREQUENCY

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
580	CFCA	517	Edmonton, Alta.			
580	CFCK	517	Edmonton, Alta.			
580	CNRE	517	Edmonton, Alta.			
600	CFCH	500	Iroquois Falls, Ont.			
666	CFRC	450	Kingston, Ont.			
690	CFAC	435	Calgary, Alta.			
690	CFCN	435	Calgary, Alta.			
690	CFHC	435	Calgary, Alta.			
690	CHBC	435	Calgary, Alta.			
690	CHCM	435	Calgary, Alta.			
690	CHXC	435	Ottawa, Ont.			
690	CKCO	435	Ottawa, Ont.			
690	CKCX	435	Calgary, Alta.			
690	CKLC	435	Calgary, Alta.			
690	CNRC	435	Calgary, Alta.			
690	CNRO	435	Ottawa, Ont.			
730	CFCF	411	Montreal, P. Q.			
730	CFYC	411	Vancouver, B. C.			
730	CHYC	411	Montreal, P. Q.			
730	CKAC	411	Montreal, P. Q.			
730	CKCD	411	Vancouver, B. C.			
730	CKFC	411	Vancouver, B. C.			
730	CNRM	411	Montreal, P. Q.			
780	CKY	384	Winnipeg, Man.			
780	CNRW	384	Winnipeg, Man.			
840	CFCA	357	Toronto, Ont.			
840	CHIC	357	Toronto, Ont.			
840	CHNC	357	Toronto, Ont.			
840	CNRT	357	Toronto, Ont.			
880	CFCU	341	Hamilton, Ont.			
880	CHCS	341	Hamilton, Ont.			
880	CKOC	341	Hamilton, Ont.			
910	CFCT	330	Victoria, B. C.			
910	CFQC	330	Saskatoon, Sask.			
910	CHUC	330	Saskatoon, Sask.			
910	CJCF	330	Kitchener, Ont.			
910	CJGC	330	London, Ont.			
910	CNRS	330	Saskatoon, Sask.			
960	CJCM	312	Monti Joli, P. Q.			
960	CKCK	312	Regina, Sask.			
960	CNRA	312	Moncton, N. B.			
960	CNRR	312	Regina. Sask.			
1030	CFXC	291	New Westminster, B.C.			
1110	CJCL	270	Montreal, P. Q.			
1210	CFKC	248	Thorold, Ont.			

Continued from page 8

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1150	WDBR	261	Boston, Mass			
1150	WEAM	261	N. Plainfield, N. J.			
1150	WMAZ	261	Macon, Ga.			
1150	WMU	261	Washington, D. C.			
1150	WOAC	261	Lima, Ohio			
1150	WPSC	261	State College, Pa.			
1150	WRR	261	Dallas, Tex.			
1150	WSKC	261	Bay City, Mich			
1150	WTAR	261	Norfolk, Va.			
1150	WTAZ	261	Lambertville, N. J.			
1160	KFCZ	259	Omaha, Nebr.			
1160	KFDH	259	Tucson, Ariz.			
1160	KFJX	259	Cedar Falls, Iowa			
1160	KFUL	259	Galveston, Tex.			
1160	KRE	259	Berkeley, Calif.			
1160	WAAD	259	Cincinnati, Ohio			
1160	WADC	259	Akron, Ohio			
1160	WDBC	259	Lancaster, Pa.			
1160	WDBY	259	Chicago, Ill.			
1160	WFBY	259	Ft. Ben. Harrison, Ind.			
1160	WHBN	259	St. Petersburg, Fla.			
1160	WHEC	259	Rochester, N. Y.			
1160	WNAL	259	Omaha, Nebr.			
1170	KELP	256	Cedar Rapids, Iowa			
1170	KFIQ	256	Yakima, Wash.			
1170	KFCF	256	Walla Walla, Wash			
1170	WAFD	256	Port Huron, Mich			
1170	WBAX	256	Wilkes Barre, Pa			
1170	WBDC	256	Grand Rapids, Mich			
1170	WDOD	256	Chattanooga, Tenn.			
1170	WEBT	256	Dayton, Ohio			
1170	WFBK	256	Hanover, N. H.			
1170	WGBN	256	La Salle, Ill.			
1170	WHBP	256	Johnstown, Pa.			
1170	WRAA	256	Houston, Tex.			
1170	WRAK	256	Escanaba, Mich.			
1170	WRHF	256	Washington, D. C.			
1170	WSAD	256	Providence, R. I.			
1180	KFEL	254	Denver, Colo.			
1180	KFJZ	254	Fort Worth, Tex.			
1180	KFLR	254	Albuquerque, N. M			
1180	KFMB	254	Little Rock, Ark.			
1180	KFNG	254	Coldwater, Miss.			
1180	KFOJ	254	Corvallis, Ore.			
1180	KFQB	254	Fort Worth, Tex.			
1180	KFUY	254	Butte, Mont.			
1180	WDBD	254	Martinsburg, W. Va.			
1180	WEAI	254	Ithaca, N. Y.			
1180	WFBR	254	Baltimore, Md.			
1180	WFBZ	254	Galesburg, Ill.			
1180	WGBA	254	Baltimore, Md.			
1180	WHBC	254	Canton, Ohio			
1180	WIAS	254	Burlington, Iowa			
1180	WJAK	254	Greentown, Ind.			
1180	WNAD	254	Norman, Okla.			
1180	WSAR	254	Fall River, Mass.			
1180	WTAQ	254	Osseo, Wis.			
1190	KFCY	252	Le Mars, Iowa			
1190	KFGD	252	Chickasha, Okla.			
1190	KFHA	252	Gunnison, Colo.			
1190	KFOY	252	St. Paul, Minn.			
1190	KFPL	252	Dublin, Tex.			
1190	KFQT	252	Denison, Tex.			
1190	KFWB	252	Hollywood, Calif.			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1190	WBBS	252	New Orleans, La.......			
1190	WBS	252	Newark, N. J.........			
1190	WFBL	252	Syracuse, N. Y........			
1190	WFBQ	252	Raleigh, N. C.........			
1190	WGBX	252	Orono, Me............			
1190	WQAS	252	Lowell, Mass..........			
1190	WSRO	252	Hamilton, Ohio........			
1190	WTAL	252	Toledo, Ohio..........			
1200	KDPM	250	Cleveland, Ohio.......			
1200	KFBG	250	Tacoma, Wash.........			
1200	KFDX	250	Shreveport, La........			
1200	KFFV	250	Lamoni, Iowa.........			
1200	KFGX	250	Orange, Tex...........			
1200	KFKQ	250	Conway, Ark..........			
1200	KGB	250	Tacoma, Wash.........			
1200	KMO	250	Tacoma, Wash.........			
1200	WCAX	250	Burlington, Vt.........			
1200	WFBC	250	Knoxville, Tenn.......			
1200	WHBA	250	Oil City, Pa...........			
1200	WHBY	250	West De Pere, Wis.....			
1200	WIAD	250	Philadelphia, Pa.......			
1200	WLAL	250	Tulsa, Okla...........			
1200	WMBB	250	Chicago, Ill...........			
1200	WNAB	250	Boston, Mass..........			
1200	WNAT	250	Philadelphia, Pa.......			
1200	WQAN	250	Scranton, Pa..........			
1200	WSY	250	Auburn. Ala...........			
1200	WTAY	250	Oak Park, Ill..........			
1200	WWAD	250	Philadelphia, Pa.......			
1210	KFBK	248	Sacramento, Calif......			
1210	KFCC	248	Helena, Mont.........			
1210	KFEC	248	Portland, Ore.........			
1210	KFIF	248	Portland, Ore.........			
1210	KFJB	248	Marshalltown, Iowa...			
1210	KFLB	248	Menominee, Mich......			
1210	KFNY	248	Helena, Mont.........			
1210	KFOX	248	Omaha, Nebr.........			
1210	KFRB	248	Beeville, Tex..........			
1210	KFSY	248	Helena, Mont.........			
1210	KFUZ	248	Virginia, Minn........			
1210	KFVI	248	Houston, Tex..........			
1210	KWG	248	Stockton, Calif........			
1210	WBBG	248	Mattapoisett, Mass....			
1210	WBBV	248	Johnstown, Pa.........			
1210	WEW	248	St. Louis, Mo.........			
1210	WGAL	248	Lancaster, Pa.........			
1210	WGBK	248	Johnstown, Pa.........			
1210	WMAY	248	St. Louis, Mo.........			
1210	WNAP	248	Springfield, Ohio......			
1210	WRAL	248	St. Croix Falls, Wis....			
1220	KFJI	246	Astoria, Oregon.......			
1220	KFJY	246	Fort Dodge, Iowa.....			
1220	KFOJ	246	Moberly, Mo..........			
1220	KUO	246	San Francisco, Calif....			
1220	WABX	246	Mt. Clemens, Mich....			
1220	WCAZ	246	Carthage, Ill..........			
1220	WEBD	246	Anderson, Ind.........			
1220	WQAE	246	Springfield, Vt........			
1220	WSOE	246	Milwaukee, Wis.......			
1230	KUOM	244	Missoula, Mont.......			
1230	WABN	244	LaCrosse, Wis.........			
1230	WAMD	244	Minneapolis, Minn....			
1230	WBAN	244	Paterson, N. J.........			
1230	WCBJ	244	Jennings, La..........			
1230	WDAY	244	Fargo, N. Dak.........			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings		
1230	WEBR	244	Buffalo, N. Y.			
1230	WHBV	244	Columbus, Ga.			
1230	WNAX	244	Yankton, S. Dak.			
1230	WRAM	244	Galesburg, Ill.			
1230	WSAZ	244	Pomeroy, Ohio			
1230	WTAT	244	Boston, Mass			
1230	WWAO	244	Houghton, Mich.			
1240	KFPM	242	Greenville, Tex.			
1240	KFPX	242	Pine Bluff, Ark.			
1240	KFRF	242	Alexandria, La.			
1240	KFUJ	242	Breckenridge, Minn.			
1240	KFUM	242	Colorado Springs, Colo.			
1240	KFVC	242	Camden, Ark.			
1240	KLS	242	Oakland, Calif.			
1240	KZM	242	Oakland, Calif.			
1240	WABY	242	Philadelphia, Pa.			
1240	WCBH	242	Oxford, Miss			
1240	WDBP	242	Superior, Wis.			
1240	WEBC	242	Superior, Wis.			
1240	WEBK	242	Grand Rapids, Mich.			
1240	WGBB	242	Freeport, N. Y.			
1240	WSL	242	Utica, N. Y.			
1240	WTAP	242	Cambridge, Ill.			
1240	WTAU	242	Tecumseh, Nebr.			
1240	WWAE	242	Joliet, Ill.			
1250	KFAB	240	Lincoln, Nebr.			
1250	KFHL	240	Oskaloosa, Iowa			
1250	KFLX	240	Galveston, Tex.			
1250	KFNL	240	Paso Robles, Calif.			
1250	KFRL	240	Grand Forks, N. Dak.			
1250	KFVE	240	St. Louis, Mo.			
1250	KGY	240	Lavey, Wash.			
1250	WABI	240	Bangor, Me.			
1250	WCAT	240	Rapid City, S. Dak.			
1250	WCBI	240	Bemis, Tenn.			
1250	WDBO	240	Winter Park, Fla.			
1250	WFBB	240	Eureka, Ill.			
1250	WGBI	240	Scranton, Pa.			
1250	WHAP	240	Brooklyn, N, Y.			
1250	WHBB	240	Stevens Point, Wis.			
1250	WKAD	240	E. Providence, R. I.			
1250	WOAX	240	Trenton, N. J.			
1250	WSMH	240	Owosso, Mich.			
1260	KFCB	238	Phoenix, Ariz.			
1260	KFPG	238	Los Angeles, Calif.			
1260	WBBP	238	Petoskey, Mich.			
1260	WBBZ	238	Indianapolis, Ind.			
1260	WCUW	238	Worcester, Mass			
1260	WRAW	238	Reading, Pa.			
1270	KFCL	236	Los Angeles, Calif.			
1270	KFLU	236	San Benito, Tex.			
1270	KFOC	236	Whittier, Calif.			
1270	KFPV	236	San Francisco, Calif.			
1270	KFVG	236	Independence, Kans.			
1270	KJBS	236	San Francisco, Calif.			
1270	WBOQ	236	Richmond Hill, N.Y.			
1270	WCBQ	236	Nashville, Tenn.			
1270	WDBT	236	Hattiesburg, Miss.			
1270	WFBI	236	Camden, N. J.			
1270	WFBJ	236	Collegeville, Minn.			
1270	WGBT	236	Greenville, S. C.			
1270	WIBA	236	Madison, Wis.			
1270	WRAN	236	Waterloo, Iowa			
1280	KFNJ	234	Warrensburg, Mo.			
1280	KFOL	234	Marengo, Iowa			

Frequency Kilocycles	Call Signal	Wave Length Meters	Location of Station	Dial Settings
1280	KFON	234	Long Beach, Calif.	
1280	KFQU	234	Holy City, Calif.	
1280	KFUP	234	Denver, Colo	
1280	KMJ	234	Fresno, Calif.	
1280	WDBQ	234	Salem, N. J.	
1280	WEAA	234	Flint, Mich	
1280	WEBE	234	Cambridge, Ohio	
1280	WEBZ	234	Savannah, Ga.	
1280	WFBD	234	Philadelphia, Pa.	
1280	WGBM	234	Providence, R. I.	
1280	WGBQ	234	Menominie, Wis.	
1280	WHBJ	234	Ft. Wayne, Ind.	
1280	WJBC	234	LaSalle, Ill.	
1280	WKAP	234	Cranston, R. I.	
1280	WQAC	234	Amarillo, Tex.	
1290	KFEY	232	Kellogg, Idaho	
1290	KFUS	232	Oakland, Calif.	
1290	KFUW	232	Moberly, Mo.	
1290	WDBX	232	New York, N. Y.	
1290	WDBZ	232	Kingston, N. Y.	
1290	WEBA	232	Highland Park, N. J.	
1290	WHAG	232	Cincinnati, Ohio	
1290	WHBM	232	Chicago, Ill.	
1290	WHBQ	232	Memphis, Tenn	
1290	WJBD	232	Ashland, Wisc.	
1290	WNJ	232	Newark, N. J.	
1290	WSRF	232	Broadlands, Ill.	
1300	KDLR	231	Devils Lake, N. Dak.	
1300	KFAN	231	Moscow, Idaho	
1300	KFDZ	231	Minneapolis, Minn.	
1300	KFER	231	Fort Dodge, Iowa	
1300	KFOT	231	Wichita, Kans.	
1300	KFPR	231	Los Angeles, Calif.	
1300	KFQC	231	Taft, Calif.	
1300	WBRE	231	Wilkes Barre, Pa.	
1300	WCBY	231	Buck Hill Falls, Pa.	
1300	WFBT	231	Pitman, N. J.	
1300	WHBG	231	Harrisburg, Pa.	
1300	WHBK	231	Ellsworth, Me.	
1300	WHBO	231	Pawtucket, R. I.	
1300	WIBF	231	Wheatland, Wis.	
1300	WKBE	231	Webster, Mass.	
1300	WLAX	231	Greencastle, Ind.	
1300	WNAR	231	Butler, Mo.	
1300	WTAX	231	Streator, Ill.	
1310	KFLV	229	Rockford, Ill.	
1310	KFQG	229	Los Angeles, Calif.	
1310	KPPC	229	Pasadena, Calif.	
1310	WAIT	229	Taunton, Mass.	
1310	WBBL	229	Richmond, Va.	
1310	WCBC	229	Ann Arbor, Mich.	
1310	WCMB	229	Baltimore, Md.	
1310	WDBJ	229	Roanoke, Va.	
1310	WSAJ	229	Grove City, Pa.	
1310	WSAN	229	Allentown, Pa.	
1310	WSAU	229	Chesham, N. H.	
1320	KFNV	227	Santa Rosa, Calif.	
1320	WABA	227	Lake Forest, Ill.	
1320	WDBK	227	Cleveland, Ohio	
1320	WGBL	227	Elyria, Ohio	
1320	WHBI	227	Chesaning, Mich.	
1330	KFFR	225	Sparks, Nevada	
1330	KFGQ	225	Boone, Iowa	
1330	KFIU	225	Juneau, Alaska	
1330	KFOR	225	David City, Nebr.	

1330	KFQZ	225	Hollywood, Calif......			
1330	KQW	225	San Jose, Calif........			
1330	WABU	225	Camden, N. J.........			
1330	WBBA	225	Newark, Ohio.........			
1330	WBBM	225	Chicago, Ill...........			
1330	WEBL	225	U. S. (Portable).......			
1330	WEBM	225	Mobile Station........			
1330	WEBQ	225	Harrisburg, Ill.........			
1330	WEBY	225	Roslindale, Mass......			
1330	WFBE	225	Seymour, Ind.........			
1330	WFBN	225	Bridgewater, Mass.....			
1330	WGBG	225	Thrifton, Va..........			
1330	WIBO	225	Chicago, Ill...........			
1340	KFBL	224	Everett, Wash.........			
1340	KFQP	224	Iowa City, Iowa......			
1340	KFRN	224	Hanford, Calif.........			
1340	KFUR	224	Ogden, Utah..........			
1340	KFUU	224	San Leandro, Calif.....			
1340	WBBU	224	Monmouth, Ill.........			
1340	WRAF	224	Laporte, Ind..........			
1350	KFRZ	222	Hartington, Nebr......			
1350	WBBW	222	Norfolk, Va...........			
1350	WBES	222	Tacoma Park, Md.....			
1350	WDBF	222	Youngstown, Ohio.....			
1350	WHBD	222	Bellefontaine, Ohio....			
1350	WHBF	222	Rock Island, Ill.......			
1350	WHBH	222	Culver, Ind...........			
1350	WIBC	222	St. Petersburg, Fla.....			
1350	WIBG	222	Elkins Park, Pa........			
1360	KFQH	220	Burlingame, Calif......			
1360	KFRW	220	Olympia, Wash........			
1360	KZRQ	220	Manila, P. I...........			
1360	WCBU	220	Arnold, Pa............			
1360	WHBL	220	Logansport, Ind.......			
1360	WQAA	220	Parkesburg, Pa........			
1370	KFVH	219	Manhattan, Kans......			
1370	WGBY	219	New Lebanon, Ohio....			
1370	WHBU	219	Anderson, Ind.........			
1370	WTHS	219	Flint, Mich............			
1380	KFRX	217	Pullman, Wash........			
1380	WCBZ	217	Chicago Heights, Ill...			
1380	WFKB	217	Chicago, Ill...........			
1380	WGBF	217	Evansville, Ind........			
1380	WJD	217	Granville, Ohio........			
1390	KFBE	216	San Luis Obispo, Calif..			
1390	KFQW	216	North Bend, Wash.....			
1390	WHBR	216	Cincinnati, Ohio.......			
1390	WHBW	216	Philadelphia, Pa.......			
1400	KFAW	214	Santa Ana, Calif.......			
1400	KFWF	214	St. Louis, Mo.........			
1410	KFRQ	213	Portland, Ore.........			
1410	WGBW	213	Spring Valley, Ill......			
1410	WHBX	213	Punxsutawney, Pa.....			
1420	KFRP	211	Redlands, Calif........			
1420	KFWC	211	Upland, Calif.........			
1430	KDZB	210	Bakersfield, Calif......			
1430	KFQR	210	Oklahoma City, Okla..			
1430	WGBH	210	Portable in N. E. States			
1430	WIBE	210	Martinsburg, W. Va...			
1430	WKAV	210	Laconia, N. H.........			
1430	WTAC	210	Johnstown, Pa.........			
1440	KFVK	208	Hollywood, Calif......			
1440	WHBS	208	Mechanicsburg, Ohio..			
1450	WABW	207	Wooster, Ohio........			
1450	WHBT	207	Downers Grove, Ill....			
1460	KFVD	205	San Pedro, Calif.......			
1460	WBBH	205	Port Huron, Mich.....			
1460	WCBR	205	Providence, R. I.......			
1480	WODA	203	Paterson, N. J.........			
1500	WIBD	200	Joliet, Ill.............			

CUBAN BROADCASTING STATIONS

Call Signal	Owner of Station	Location of Station	Frequency Kilo-cycles	Wave Length Meters	Rating Oscill. Watts
PWX	Cuban Telephone Co......	Havana...........	750	400	500
2BB	Bernardo Barrie..........	"	1188	255	15
2BY	F. W. Borton............	"	1153	260	100
2CX	F. W. Borton............	"	937	320	10
2EP	El Pais..................	"	845	355	400
2HP	Credito y Contrucciones Co	"	1016	295	100
2JP	Julio Power..............	"	1110	270	20
2KP	George A. Lindeaux.......	"	1540	195	10
2LC	Luis Casas...............	"	1200	250	30
2MG	Manuel y G. Salas........	"	1070	280	20
2MK	R. V. Waters............	"	3540	85	20
2OK	Mario Garcia Velez.......	"	833	360	100
2OL	Oscar Collado............	"	1000	300	100
2RM	Rogelio Morales..........	"	1430	210	10
2RY	Raoul Karman............	"	1090	275	20
2SZ	Homero Sanchez..........	"	1670	180	10
2TW	Roberto E. Ramirez......	"	1304	230	20
2XX	Antonio A. Ginard........	"	2000	150	5
5AZ	Ernesto V. Figueroa......	Matanzas	1500	200	50
5BY	Leon Gonzalez Velez......	"	1580	190	10
5EV	Leopoldo V.Figueroa Colon	"	833	360	10
6BY	Jose Ganduxe............	Cienfuegos.........	1153	260	200
6DW	Eduardo Terry............	"	1330	225	10
6EV	Maria J. Alvarez..........	Caibarien..........	1200	250	50
6GR	Luis del Castillo..........	Cienfuegos.........	1200	250	10
6GT	Juan Pablo Ros...........	"	1580	190	5
6JQ	Eligio Cobelo............	"	1153	260	10
6HS	Santiago Ventura.........	Sangua Grande.....	1500	200	10
6KJ	Frank H. Jones..........	Tuinicu...........	1090	275	100
6KW	Frank H. Jones..........	"	890	340	100
6YR	Diego Iborra.............	Camajuani.........	1500	200	20
7AZ	Pedro Nogueras..........	Camaguey.........	1330	225	10
7BY	Eduardo V. Figueroa.....	C. Avila...........	1275	235	20
7SR	Salvador Rionda.........	C. Elia............	860	350	500
8AZ	Alfredo Brooks...........	Stgo. de Cuba......	1250	240	20
8BY	Alberto Ravelo...........	"	1200	250	100
8FU	Andres Vinnet............	"	1330	225	15
8HS	Guillermo Polanco........	"	1500	200	10
8IR	Ceferino Ramos..........	"	1580	190	20

QUALITY OF ELECTRON TUBES OF INDEPENDENT MANUFACTURE

We are appealing to all independent tube manufacturers to co-operate with us in our desire to give the readers of Radiofax definite information on the quality of their products.

We are inviting all of them to submit six tubes of each type so that we may determine the uniformity of characteristics.

A number of manufacturers have already responded to our appeal, and we trust that all who do not fear publicity will be listed in the report we hope soon to make.

RADIO LOG

Call Letter	*	LOCATION	Distance Miles	Date	Time	REMARKS (Tuning, weather, special feature, quality, etc.)
WOO		Phila., Pa	14	3/12/23	7.50	Band selections, Organ
KYW	*	Chicago, Ill.	700	"	10.15	† = 18½, ‡ = 4, O - 14, ● = 85 Clear, cool. dance music. good
WWJ	*	Detroit, Mich.	475	"	10.35	† = 16, ‡ = 4, O = 12½, ● = 80 " " vocal faint
WGY		Schenectady, N.Y.	250	"	10.40	Banquet of Artisans " " loud
WGM		Atlanta, Ga.	650	"	11.20	Quartette southern songs " " variable
WIP		Phila., Pa	14	3/13/23	7.45	After-dinner tricks. Vocal selections. Dance music
WWJ		Detroit, Mich.	475	"	10.15	Speeches, songs, orchestra selections. Cloudy. Faint
WJZ		Newark, N.J.	75	"	10.30	Songs and dance music. Good but not loud.
WFI		Phila., Pa.	14	3/14/23	8.05	Orchestra-dance music. Organ recital.
WJAX		Cleveland, Ohio	350	"	10.35	Talk on insecticides. Dance music. Clear, cold. Loud, good.
WOR		Newark, N.J.	75	"	10.50	Radio hints
WDAF	*	Kansas City, Mo.	1050	"	11.25	† = 17, ‡ = 4, O = 16½, ● = 80. Dance music. Good
KYW		Chicago, Ill.	700	"	11.40	Violin selections. Distinct but not loud
WOO		Phila., Pa.	14	3/15/23	7.50	Vocal and instrumental. Organ selections
WHAZ	*	Troy, N.Y.	220	"	8.55	Agricultural lecture † = 16½, ‡ = 4, O = 10, ● = 70
KDKA		Pittsburgh, Pa	300	"	9.30	Piano selections. Cloudy-cold. Fading.

*First time station was heard † = Ant. Cond. ‡ = Ind. Sw. O = Tickler ● = Potentiometer † = X =

MARCH
12–18
EVENINGS

LEFAX FILING INDEX

Hints on Use of Radio Log

Put asterisk in column 2 only the first time you hear a certain station. This will allow you to quickly find the total number of different stations heard on your set by simply counting the asterisks.

The symbols at bottom of sheet are to be assigned to your various tuning adjustments. This will save space in the Remarks column as shown. Six symbols are provided. If you do not need all of them for dial settings, use the balance for indications of weather conditions, quality, etc.

Dial settings need be recorded but once. They can be quickly found by glancing over the stations marked with an asterisk. It is wise, however, to check these settings occasionally as a slight change may be made in the wave length of the transmitter.

Indicate change of date by short dashes as shown, or leave a blank line between one day's entries and another's.

When additions or improvements are made in your receiving set, leave a blank line or two and give details. in Remarks column. This will show the reasons for the improved results recorded subsequently. Even slight improvements, like a new B battery should be so recorded.

If your equipment allows switching over from antenna to loop indicate type of aerial used in Remarks column.

The regular Radio Log is ruled on both sides and will allow 32 entries.

Price 25c (in U. S. A.) for pack of 40 sheets.

Order from your stationer or

LEFAX, Inc.

9th & Sansom Streets - Philadelphia, Pa.

LEFAX FILING INDEX

LEFAX FILING INDEX

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ADDRESSES

LEFAX FILING INDEX

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Address...

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Phone...

Name...

Address...

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LEFAX FILING INDEX

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10 Lines = 1 Inch

GETTING THE MOST VALUE OUT OF YOUR LEFAX RADIO HANDBOOK

To get the best possible results from a receiving set is the chief aim and purpose of every individual who takes an interest in the new art of radio, and the only way to get good results is by obtaining a thorough knowledge of every worthwhile piece of equipment now being manufactured. Realizing the importance of a service defining the value and uses of reliable radio apparatus, we have incorporated such a service free with the Lefax Radio Handbook.

The apparatus sheets included in this handbook will enable you to pick to advantage the apparatus that is most suitable to your needs. They fulfill the function of a show-room, where you can study the advantages of each piece of apparatus or complete set and compare them in price and suitability to your needs. Most important of all, you will make no mistake in selecting any of the equipment described on the apparatus sheets, because they are being manufactured by reputable concerns whose products have been thoroughly tested in our laboratory.

As the capacity of the Lefax Handbook is limited, we have devised a filing box containing thirty-two index cards, for the purpose of filing additional hook-ups, memoranda, apparatus and data sheets. Each index card covers one subject only. This facilitates easy filing and reference to the sheets. (See illustration on next page.)

KEEP YOUR OWN NOTES AND DIAGRAMS IN THIS BOOK TOO

Whatever you want to remember, put it on one of the Lefax blank sheets included in this binder and you will have it when you want it. Additional blank sheets can be obtained at nominal cost, as indicated below.

A Few Leading Forms

Complete list will be sent on request.

Price in U. S. (all forms) .... 25c per pack postpaid.

Form No.		*No. sheets per pack*
7	Yellow scratch paper	100
8	White paper, unruled, single sheets ($6\frac{3}{4}$x$3\frac{3}{4}$)	50
22	do do double sheets ($6\frac{3}{4}$x7)	20
56	do do triple sheets ($6\frac{3}{4}$x$10\frac{1}{2}$)	13
9	Horizontal ruled	50
10	Quadrille ruled, 6 lines to inch	50
71	Onion skin (tracing) paper	40
91	Perforated reminder sheets	40
194	Addresses	40
92	Daily Memo or Diary	40
14	Journal, 2-column	40
323	Personal Expense record	40
336	Radio Log	40
12	Cross-section paper, 20 lines to inch, single	30
19	do do double	15
51	do do triple	10

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Lefax Filing Box

for Radio Apparatus Sheets, Circuit Diagrams, Notes and Data

Price of Filing Box complete with 32 index cards, and ruled and unruled sheets for circuit diagrams, memoranda, etc. (capacity 800 sheets), $1.50, postpaid.

LEFAX, Inc., 9th & Sansom Sts., Philadelphia, Pa.